

1965

# Factors associated with the dissemination of Salmonellae in turkey products and processing plants

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FACTORS ASSOCIATED WITH THE DISSEMINATION  
OF SALMONELLAE IN TURKEY PRODUCTS AND  
PROCESSING PLANTS.

Iowa State University of Science and Technology,  
Ph.D., 1965  
Bacteriology

University Microfilms, Inc., Ann Arbor, Michigan

FACTORS ASSOCIATED WITH THE DISSEMINATION  
OF SALMONELLAE IN TURKEY PRODUCTS AND  
PROCESSING PLANTS

by

Frank Leon Bryan

A Dissertation Submitted to the  
Graduate Faculty in Partial Fulfillment of  
The Requirements for the Degree of  
DOCTOR OF PHILOSOPHY

Major Subject: Bacteriology

Approved:

Signature was redacted for privacy.

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1965

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## INTRODUCTION

Salmonellosis is a communicable disease readily transmissible to man from domestic animals and food products of animal origin. In both man and animals the disease is manifested by a gastrointestinal illness, frequently severe in the young, the elderly, and the debilitated. Furthermore, it commonly produces the symptomless carrier state in healthy adults.

The reported incidence of human salmonellosis is increasing. Whether or not this is a true increase or merely better diagnosis and reporting is conjecture. However, it is believed by many investigators that there is an increase in incidence of salmonellosis in both man and animals (World Health Organization, 1959; Edwards, 1964; and Galton et al., 1964b).

In exploring the epidemiology of salmonellosis, the changing food habits of man and animals must be considered. Foods of animal origin which are mass produced and preserved in a manner which does not destroy pathogens are widely distributed and may contribute to the dissemination of Salmonellae. According to present day morbidity reports, poultry and poultry products represent important reservoirs of Salmonellae. Turkey meat, for instance, has frequently been found to be a cause of salmonellosis in humans.

Poultry and poultry products represent an important part of the American diet. More poultry meat is consumed per capita in the United States than in any other country in the world, and consumption is increasing. Part of this increase is due to the marketing of "further

processed" turkey products. According to data compiled by the U.S. Department of Agriculture (1965), "further processed" and cut up turkey products represent 21.6% of federally inspected and passed turkey meat. "Further processed" turkey products, such as turkey rolls, are receiving increased use by the restaurant industry and institutions as labor saving and portion control items. Cut-up turkey products are also being accepted by the homemaker. To meet these demands poultry processing plants are becoming "factory kitchens". Thus, with this potential for mass distribution of potentially hazardous food products, a study of the extent and the source of contamination in these products is timely and necessary.

The present investigation was undertaken for the purpose of determining the incidence of Salmonellae in "further processed" turkey products and evaluating the influence of sources of contamination by Salmonellae of turkeys on the farm and of turkey products in the processing plant. In addition, experiments were undertaken to evaluate the effectiveness of the thermal processing of turkey rolls in destroying Salmonellae.

## REVIEW OF LITERATURE

## Incidence of Salmonellosis in the United States

Human outbreaks and cases

Human salmonellosis is a disease of world-wide distribution, high incidence, and low mortality. The real incidence in the United States is unknown. In fact, Newell (1959) has pointed out that no country possesses a reasonable appraisal of its occurrence. Reporting of human or animal salmonellosis is not universally required and, until the advent of the Salmonella Surveillance Program of the Public Health Service, information on the occurrence of salmonellosis was not actively sought on the national level. Meyer (1953) emphasized that the summaries published annually by the National Office of Vital Statistics were based on woefully inadequate reporting from a minority of the states, and that in most instances the etiological agents of food-borne infections were not determined accurately. Dauer (1961) has shown this to be true when he summarized a five-year period of state reports. He observed that more than half of the states had reported an average of less than one outbreak per year, and only six states reported an average of over two outbreaks. He also stated that during a nine-year period ending in 1960, 44.8% of the reported outbreaks were of unknown etiology.

Frank (1940), Dauer (1959 and 1961), Edwards (1963), Lewis (1963), and the Food Protection Committee of the Food and Nutrition Board (1964) state several factors that have contributed to the poor reporting of food-borne diseases, including:



- a) The unwillingness of persons with mild symptoms of gastroenteritis to seek medical attention or to report their illness to the health department
- b) The dispersal of persons from eating places where contaminated food may have been consumed, or the wide distribution of foodstuffs
- c) Failure of physicians to elicit from one or a few patients with gastroenteritis sufficient information to justify a report
- d) Failure to obtain stool cultures from patients
- e) Failure of health departments to conduct necessary field investigations of suspected outbreaks because of other demands
- f) Inability to establish causative connections during investigations
- g) Inadequate laboratory study due to lack of specimens or resources to do the work
- h) Reluctancy of public and private organizations to become involved in situations that may lead to unfavorable publicity, legal actions, or possible financial loss
- i) Insufficient administrative support to generate the teamwork required to collect, evaluate, and report on suspected outbreaks of food-borne illness
- j) Locally investigated outbreaks are not always reported to state health authorities due to poor liaison or other reasons

This last reason has been pointed out in a survey conducted by the International Association of Milk and Food Sanitarians (1961).

In spite of these situations, some significance of the problem can be drawn from the reported cases and outbreaks. Dauer (1952) summarized information regarding only nine outbreaks of salmonellosis between the years 1938-1951 and subsequently reported (Dauer, 1953-1961) an average of 23 outbreaks (range 16-31) between 1952-1960. In a study of 926 outbreaks

of gastroenteritis occurring between the years 1945-1947, Feig (1950) reported 72 outbreaks in which Salmonellae were involved. MacCready et al. (1957) observed a fourfold increase in incidence in Massachusetts from 1940-1955 and nearly a sevenfold increase in that state from 1950-1955, while the total specimens from which these recoveries were made increased less than twofold. (Edwards (1958) compared the food-borne outbreaks reported in Great Britain with those reported in the United States during a three-year period (1953-1955). He noted twice as many staphylococcal outbreaks and 28 times as many outbreaks of salmonellosis per 100,000 population in England and Wales as in the United States. He suggested that this great difference was not real, but that it indicated more complete reporting of salmonellosis in Great Britain. Edwards (1958) has further shown that there was over a sevenfold increase in human cases of salmonellosis, as represented by cultures sent to the National Salmonella Center during a ten-year period ending in 1955. These tabulations have recently been brought up to date by Galton et al. (1964b) for the period 1951-1961, and over a fourfold increase was noted in the number of human cases. During all these above-mentioned periods, there has been a steady decrease in the reported cases of typhoid fever. In April, 1962, the Communicable Disease Center initiated a Salmonella Surveillance Program covering eight states and by January, 1963 a nationwide surveillance was in effect. During 1963, 18,649 human isolations and 63 deaths were reported to the Salmonella Surveillance Unit. The ten most common serotypes isolated from humans during 1963 were S. typhimurium, S. derby, S. heidelberg, S. newport, S. infantis, S. enteritidis, S. typhi, S. saint paul, S. oranienburg, and S. montevideo (U.S. Department of Health,

Education, and Welfare, 1964). In 1964, the total human isolations increased to 21,132. This represented an 11% increase over the previous year. The same serotypes were in the list of the ten most common serotypes recovered from humans (U.S. Department of Health, Education, and Welfare, 1965). According to Galton et al. (1964b), some of this increase in the number of reported human cases of salmonellosis was due to improved methods and facilities for the detection of Salmonellae, an increased general awareness of salmonellosis as a disease problem, further development of disease reporting, and a marked increase in the use of Salmonella reference centers. However, Edwards (1964) and Galton et al. (1964b) believe that a real increase in incidence of salmonellosis has also occurred. Most of the isolations of Salmonella were from sporadic cases rather than from cases associated with outbreaks. Edwards (1963) stated that it is unlikely that many cases of salmonellosis are sporadic and not connected with outbreaks.

#### Salmonellosis in turkeys

Salmonellosis in fowl is a well established problem and has been reviewed by Buxton (1957), Hall (1959), VanRoekel (1959), and Williams (1959).

Edwards (1958) and Galton and Steele (1961) have stated that poultry probably constitutes the largest single reservoir of Salmonellae among animals. Between 1934 and 1947, more than 50% of 12,331 cultures examined at the National Salmonella Center by Edwards et al. (1948a) were isolated from domestic fowl. In California, Perelli-Minetti et al. (1948) recovered Salmonellae from 41.4% of all turkeys presented for autopsy. Smith and Buxton (1951) isolated Salmonellae from the feces of 2.5% of 650 turkeys.

During routine necropsy, 30 serotypes of Salmonella were isolated from 21% of 1,148 turkey poultts examined by Lukas and Bradford (1954). Gordon (1959) found that salmonellosis was the third most common cause of death in poultry, and Hinshaw (1959) stated that salmonellosis was one of the major causes of losses in young turkeys.

In a 4 1/2 year period ending in July 1961, Moran (1961) typed 6,216 Salmonella cultures from animal sources. Avian species accounted for 78.6%, and turkeys accounted for 39.4% of all positive samples. The greatest variety of serotypes (57) occurred in turkeys. Of these serotypes, 17 averaged less than one identification per year, and 28 averaged less than two identifications per year. Domestic and wild fowl accounted for 58.1% of all non-human isolations of Salmonellae made in 1963, while turkeys accounted for 27.2% of the total, according to the U.S. Department of Health, Education, and Welfare (1964).

Many of the Salmonella cultures isolated from poultry came from apparently healthy animals that were reactors to the pullorum test and were submitted for culture under the National Poultry and Turkey Improvement Plans. Thus, the above results may be biased; however, poultry still appear to be a major reservoir of Salmonellae.

Forty serotypes were isolated by Fenstermacher (1952) from turkeys in Minnesota. Williams (1959) listed 102 serotypes of Salmonella, excluding S. pullorum and S. gallinarum, that have been recovered from chickens and/or turkeys in the United States. From a survey of the available world-wide literature, as well as from canvassing research workers and diagnostic laboratory directors, Hinshaw (1959) compiled a list of 96 serotypes of Salmonella, not including S. pullorum and S. gallinarum,

isolated from turkeys. Most of the Salmonella serotypes recovered from poultry have also been found to infect man.

Hinshaw et al. (1944) found that of 19 serotypes associated with outbreaks among turkeys in California, S. typhimurium accounted for 60%. According to the U.S. Department of Health, Education, and Welfare (1964), in 1963, S. typhimurium was cultured from turkeys more frequently than any other serotype (16.7%). Other types frequently encountered were S. heidelberg, S. saint paul, S. schwarzengrund, S. bredeney, S. anatum, and S. chester. In the 4 1/2 year review by Moran (1961) the preceding serotypes, as well as S. san diego, S. newport, S. muenchen, and S. infantis were the common isolates from turkeys.

A number of independent investigators have pointed out the similarity between the incidence of Salmonella serotypes in man and poultry, with the exception of S. pullorum, S. cholera-suis, and S. typhi (Darby and Stafseth, 1942; Hinshaw et al., 1944; Kessel et al., 1945; and Edwards et al., 1948a,b).

#### Food-borne diseases associated with poultry products

Poultry meat has been frequently incriminated as the cause of food-borne diseases. In regard to outbreaks associated with poultry, the following data can be extrapolated from food-borne disease summaries, reports to the National Office of Vital Statistics, and reports to the Communicable Disease Center. However, the problems of incomplete reporting bias the figures. Frank (1940) first reviewed, at the national level, food-borne diseases along with water- and milk-borne diseases, which occurred in 1938. He reported that poultry was responsible for only five

outbreaks and 94 cases. The next year, Fuchs (1941) listed 35 paratyphoid outbreaks and 1,880 cases as well as five typhoid outbreaks and 79 cases. Poultry was responsible for seven outbreaks and 97 cases. Getting (1943) reported that from 1938-1941 there were 48 food-borne outbreaks involving 1,744 cases associated with poultry. In addition, there were eight outbreaks and 359 cases caused by poultry dressing. During this period, poultry as a source of outbreaks and cases was surpassed only by meat preparations and cream-filled pastry. Feig (1950) reported that from 1945-1947, 22% of 304 staphylococcal outbreaks, and 18% of 54 outbreaks of salmonellosis involved poultry. These were almost equally divided between chicken and turkey sources.

In Dauer's annual disease summaries, some interesting facts and trends are noted. He (1952) reported that 53 of 256 outbreaks were due to poultry products. Next, he (1953) showed that poultry and eggs were far more important than milk or water as vehicles of infection. Chickens and, more often, turkeys were responsible for illness in 39 of 143 outbreaks. A large portion of these outbreaks were proved or suspected to be salmonellosis. This report very clearly indicated that poultry and eggs constitute a large reservoir of infection, and it emphasized the need for more effective measures to prevent transmission of these infections to man. Dauer and Sylvester (1954) stated that in one-third of the outbreaks of salmonellosis, chickens or turkeys were found to be responsible. With regard to this observation, they contended that this cannot be considered an unusual finding when considering the frequency with which fowl are found to be infected with Salmonellae. The next year, they (1955) cited that the foods most frequently incriminated in food-borne

outbreaks were turkey meat, cream-filled pastry, ham, chicken, and potato salad. A year later they (1956) reported that the foods most frequently incriminated in outbreaks were turkey and chicken products, custard-filled pastry, ham, and beef. Seven of 13 outbreaks caused by Salmonellae, involving 165 cases, were due to poultry products. The following year, poultry meat was the product most often incriminated in outbreaks (Dauer and Sylvester, 1957). Turkeys accounted for a large portion, and chickens accounted for only a fraction of the total outbreaks. During the subsequent year, Dauer (1958) reported that 36 outbreaks and 2,072 cases were caused by poultry products. The number of outbreaks associated with poultry was surpassed only by outbreaks due to various kinds of meat products; however, poultry products accounted for the majority of the cases. In the following summary, Dauer and Davids (1959) cited 42 outbreaks and 1,848 cases that were caused by poultry meat, which as a group was surpassed only by red meat preparations. Turkeys were more important than chickens as the responsible agent of most reported outbreaks. In 1959, Dauer and Davids (1960) reported 37 food-borne outbreaks involving 2,247 cases due to poultry, and in 1960 Dauer (1961) reported 30 outbreaks and 1,406 cases due to this product. Only red meats and their products caused more outbreaks and cases.

According to a tabulation by Bryan (1963) of outbreaks reported to the Communicable Disease Center in 1961, 24 of 39 outbreaks and 1,151 of 1,732 cases due to poultry were caused by the consumption of turkeys. In 1962, 29 of 43 outbreaks and 3,661 of 3,974 cases associated with poultry were attributed to turkey meat. During this two-year period, turkey meat,

gravy, and/or dressing by far outranked any other single food item as a source of food-borne cases.

From the preceding reports, it may be concluded that poultry and meat products have been the sources of about half of the food-borne outbreaks reported since 1956 (Food Protection Committee of the Food and Nutrition Board, 1964). It must be again emphasized that the foregoing summary has the limitations of inadequate reporting as previously discussed. However, these reports still establish poultry, particularly turkeys, as an important vehicle for the transmission of salmonellosis and other food-borne diseases.

#### Illustrative outbreaks of salmonellosis

The literature regarding the transmission of salmonellosis from poultry to man is too voluminous to discuss in detail, so only a few examples related to turkeys or to processing plant problems will be reviewed.

Sanders et al. (1963) investigated an outbreak in which 498 of approximately 1,400 people who attended a political banquet developed gastroenteritis due to S. typhimurium. Sliced turkey meat was implicated as the common-source vehicle, and S. typhimurium was isolated from a work table surface used in the turkey preparation. Facilities for cooking and refrigerating the turkeys were inadequate. Many investigators have reported on outbreaks in which inadequate cooking failed to rid poultry of viable Salmonellae (Kendra and Siess, 1961; Ager, 1962; Condit and Link, 1962; Smith, 1963; Koomen, 1963; Fodor, 1964; Beary, 1964; and Mollohan and Cross, 1965).

Poultry meat may serve as a source of kitchen contamination that



subsequently contaminates other foods which are not heat treated. Mackel et al. (1959) illustrated this situation in their description of an outbreak involving 300 inmates of a penal institution. Evidence suggested that the frozen turkeys were infected initially, the chopping block was contaminated when the birds were prepared for roasting, and the cooked birds were recontaminated from the chopping block during slicing. S. typhimurium was recovered from the patients and from the unused frozen turkey necks.

Sanborn (1963) reported on a two phase outbreak due to S. chester. Frozen turkeys were thawed on a table and contaminated a cutting board. Roast pork was carved on the cutting board and an outbreak resulted. The cooked turkey was served without incident; however, after left-over turkey was sliced for sandwich preparation on the cutting board, another outbreak resulted. The turkey table used for thawing yielded S. chester. Sanborn (1963) cited another instance in which sliced turkey meat was responsible for an outbreak due to S. typhimurium. During the pursuant epidemiological investigation, this organism was isolated only from the cutting board on which the turkey was carved.

A similar situation wherein a food worker who had handled infected frozen eggs became ill with salmonellosis has been described by Taylor (1960). After recovery, the worker returned to work and handled ox-hearts which were sold ready-cooked to the public. An outbreak resulted. A rare serotype, S. irumu, was isolated from the patients' stools, the food worker, and the frozen eggs.

Outbreaks have been traced to processed "ready-to-eat" and partially cooked poultry meat products. McCroan (1963) reported 300 confirmed cases

and estimated that 3,000 cases of salmonellosis were due to S. blockley following the consumption of commercially prepared chicken salad. S. blockley was isolated from recalled samples of chicken salad prepared on each of the preceding 30 days. Swab samples taken from equipment in the plant and stool cultures from five workers were positive for this organism. Because of reported occurrences of recent outbreaks of S. blockley in several broiler flocks in the region, it was presumed that the organisms were introduced into the plant through infected birds and subsequently were perpetuated by workers and equipment.

Three reported outbreaks have shown an epidemiological association with turkey rolls. Fish (1963) investigated a family outbreak of salmonellosis in which turkey rolls and three other foods served at the meal responsible for the outbreak were obtained from the delicatessen counter of a supermarket. S. muenchen was isolated from all four foods, from one employee, and from the food purveyor's daughter. Subsequently, three other cases of infection caused by S. muenchen were discovered among other delicatessen customers. This was considered to be an outbreak caused by a human carrier; later information, however, suggested the possibility of S. muenchen being brought into the delicatessen via the turkey product.

During the S. derby outbreak which occurred in 1963 in northeastern hospitals, two cases of salmonellosis due to S. derby were reported from children who had no hospital contact. They gave a history of eating turkey rolls. S. derby was recovered from the rolls by the Philadelphia City Health Department (1963). Surveys of the environment of three processing plants producing turkey rolls in the Philadelphia area revealed S. derby in each plant and in the finished rolls from one plant. S. muenchen

was isolated from floor drains in two turkey roll plants and from the equipment in one of them. Five other serotypes were detected in the environment of the plants (U.S. Department of Health, Education, and Welfare, 1963).

Epidemiological evidence, as reported by Freitag et al. (1963), incriminated turkey rolls as a source of infection involving 250 students in two dining halls. S. manhattan was isolated from the ill students and from 15 of the 31 food handlers. The two dining halls were in separate buildings and completely independent with regard to equipment, personnel, and facilities. The involvement of a common food that was contaminated prior to introduction into the kitchens and served in both dining halls was suggested. The responsible rolls were produced in the plant involved in the preceding two reports. It should be further noted that in the processing of these rolls, the turkeys were cooked and then put into the casings.

Ager (1962) reported another contemporary problem involving frozen turkeys. A large mature frozen turkey was cooked on a charcoal rotisserie and served immediately after cooking. No illness resulted. Two days later the left-overs, which were not refrigerated, were served in sandwiches at a large family event, and salmonellosis resulted. Two days following this event, the turkey was recooked in an oven because it was felt to be tough and undercooked. Subsequent consumption was not marked by illness. It was concluded by the investigator that the turkey was undercooked on the rotisserie. No illness resulted on the first day since the outer portions which were exposed to higher heat from the charcoal fire were free of viable Salmonellae. Storage at room temperature for two

days provided an opportunity for multiplication of surviving Salmonellae. The deeper, inadequately cooked, portions of the turkey were consumed at the second serving.

#### Pathogenicity of the Salmonellae

The pathogenicity of several serotypes of Salmonella to healthy human volunteers was evaluated by McCullough and Eisele (1951a,b,c,d.). Illness resulted from one strain of S. meleagridis with almost eight million and ten million cells while with another strain 24 million cells were required to produce illness. With S. anatum, the range was 587,000 to 860,000 cells for one strain and 44.5 million to 67.2 million cells for another strain. S. bareilly induced illness with as few as 125,000 organisms, and S. newport caused illness with 152,000 cells. It took 15 million S. derby cells and from 1.3 billion to 10 billion S. pullorum organisms to produce illness. In a review of these investigations, Adler (1965) pointed out that the group studied were mature, healthy men previously immunized against S. typhi and from environments with the possibility of high exposure rates, and thus presumably highly resistant. He emphasized that infants, children, and patients with some other underlying disease are apparently more susceptible to salmonellosis. Hook (1961) and the U.S. Department of Health, Education, and Welfare (1964 and 1965) have shown that the majority of the cases of salmonellosis are in children, with the highest incidence in children under one year of age.

Modes of Transmission of Salmonellae to Turkeys Prior to Slaughter

Asymptomatic carrier birds

Gordenk et al. (1949) reported that S. gallinarum was transmitted from artificially infected birds to normal birds by co-habitation. The mortality among two flocks of normal birds was 45.8% and 60.9%. In work done by Hall et al. (1949), susceptible birds were put in a pen with birds sick with acute fowl typhoid. The incidence of the disease in the former was much greater than when susceptible birds were placed in a pen contaminated with S. gallinarum from which all sick birds had been removed.

Gauger and Greaves (1946a) reported fecal shedding of S. typhimurium over a period of 65 days by naturally infected adult turkeys and up to 15 days in artificially infected adult turkeys. They (1947) found that poults voided S. typhimurium in feces up to 96 days after oral administration, and they indicated that disease transmission resulted when this fecal material was ingested by susceptible poults. Buxton and Gordon (1947) observed that chickens may remain intestinal carriers of S. thompson up to 18 months. Wilson (1948) found that adult chickens may serve as intestinal carriers of S. typhimurium and S. thompson for periods up to 9-16 months. S. typhimurium was recovered from feces and tissues up to 44 days after oral infection of 6.5 week-old poults (Adler et al., 1953). Shaffer et al. (1957) reported the recovery of S. typhimurium from feces for at least 18 days after oral infection of baby chicks. Yamamoto et al. (1961) recovered S. typhimurium from 67% of adult turkeys at necropsy 35-44 days after inoculation. In this study,  $1.2 \times 10^9$

Salmonellae were inoculated in the crop, and at necropsy positive fecal cultures yielded from 10 to  $10^3$  organisms per gram.

Henderson et al. (1960) reported that disease may be established in chicks with as few as one or ten Salmonellae. S. typhimurium was found to be more pathogenic than six other serotypes tested. Morehouse and Wedman (1961) suggested that small numbers of Salmonellae may be capable of establishing at least a carrier state in nature, regardless of the source of exposure, which might manifest into overt disease at a later period, depending upon such conditions as host susceptibility and stress factors. Following an outbreak of avian salmonellosis in which morbidity was high, Abelseth and Robertson (1953) observed that most of the surviving birds continued to excrete S. typhimurium for at least 30 days after apparent recovery. They estimated that the infected birds would reach the market in an apparently healthy condition.

Bigland (1962) and Bigland et al. (1962) found a carrier rate of 4% in 200 adult turkeys from two flocks known to be infected as poults, as compared to a carrier rate of 0.5% in 600 turkeys from other flocks. Yamamoto et al. (1962) found that 32.5% of 123 flocks and 19.4% of 314 breeder turkeys were positive for Salmonellae in a three year testing program for S. typhimurium. Ranches free from Salmonellae were in some cases positive the following year. Conversely, ranches with reactor birds were sometimes negative the next year.

More than one serotype of Salmonella has been found in a flock or bird on a single occasion. Edwards and Bruner (1940) observed multiple types of Salmonellae in individual flocks. Five serotypes were isolated

from one flock in which poults were accumulated from several sources over a period of three years by Pomeroy and Fenstermacher (1941). Hinshaw et al. (1944) found multiple types on the same ranch. Edwards et al. (1948a,b) reported more than one serotype existing in the same flock in 165 instances. The isolation of two or more serotypes from a single bird was made in 51 cases; three types were found in the liver of one poult, and four types from the liver of another. Four Salmonella serotypes were isolated from one turkey farm by Ballantyne (1953).

### Eggs

Eggs have frequently been incriminated as a source of Salmonellae to poults and chicks, particularly in the case of pullorum disease (Buxton, 1957; VanRoekel, 1959).

After reviewing the available information on egg transmission of Salmonellae to poults, Hinshaw (1959) concluded that contamination and subsequent infection of the poult is mainly from infected intestinal contents coming in contact with the shell during expulsion from the body or in the nest; however, Hinshaw also stated that ovarian transmission must not be ignored. Bigland (1962) found that 17% of 242 eggs from a carrier flock were positive for Salmonellae.

In regard to ovarian transmission, Williams (1959) indicated that paratyphoid infections in turkeys may occasionally be directly transmitted through the ovaries; however, experimental evidence does not indicate that infected turkeys produce a high percentage of infected eggs. Lee et al. (1936), Cherrington et al. (1937), Hinshaw and McNeil (1943), Gibbons and Moore (1946), Gauger and Greaves (1946b), Gunderson et al.

(1954), and Yamamoto et al. (1961) were able to isolate Salmonellae from the ovaries or oviducts of turkey hens. Mallmann and Moore (1936), Cherrington et al. (1937), and Pomeroy and Fenstermacher (1939) reported the isolation of Salmonellae from "dead-in-shell" embryos.

Fecal contamination of egg shells with Salmonellae during the process of laying, from a contaminated nest, or from incubators after laying are of foremost importance in the egg transmission to poults. Hinshaw and McNeil (1943) reported that in adult carriers of S. typhimurium, 81% of the isolations were from the intestines, whereas only 17% were from reproductive organs. Wilson (1945) isolated S. typhimurium and S. thompson from the outside of egg shells. In the study by Gauger and Greaves (1946b), a much higher percentage of positive isolations were made from outside of the shells than from the egg contents, and more isolations were from the digestive tract than from the reproductive tract. S. typhimurium was not recovered from the contents of 164 eggs laid by carrier hens, although these birds excreted the organism regularly in their feces. Wilson (1948) showed higher recoveries from the shell than from the contents after the examination of over a thousand chicken eggs.

Schalm (1937) demonstrated that S. typhimurium in fecal material smeared on the surface of chicken eggs was capable of penetrating the shell and multiplying within the egg. Pomeroy and Fenstermacher (1941) mixed S. typhimurium with sterile turkey feces and smeared the mixture on one-third of the egg surface. The organisms were shown to pass through the unbroken shell and infect developing embryos during incubation. When eggs contaminated with S. oranienburg, S. montevideo, S. typhimurium, S. gallinarum, and S. pullorum were incubated at 29°C for 3-4 weeks,



all strains penetrated the shell membranes and multiplied within the eggs to populations as high as one billion cells per ml of egg meat (Stokes et al. 1956). Penetration and growth occurred as rapidly with non-motile serotypes as with motile serotypes. Williams (1959) stated that Salmonellae are able to gain entrance into the egg, to multiply in the yolk, and to infect the developing embryo which may die or hatch as an infected poult. Buxton and Gordon (1947), Gregory (1948), Lancaster and Crabb (1953), and Banwart and Ayres (1957) have shown that egg albumen has very little inhibitory effect on Salmonellae that penetrate the shell.

Wilson (1948) cautioned that mixing contaminated eggs with clean eggs in the incubator is a means of spreading infection. Proper temperature and moisture has been shown to be important in the rate of penetration through the shell. S. thompson has been shown by Buxton and Gordon (1947) to readily penetrate the shell of chicken eggs stored at 37°C, but penetration was less common in eggs stored at room temperature. Bigland and Papas (1953) reported shell penetration in 8% of eggs contaminated with S. typhimurium, 3% with S. oranienburg, 16% with S. kentucky, and none with S. bareilly.

### Feed

Mounting evidence points toward feed as a source of Salmonellae for poultry. Edwards et al. (1948a) isolated S. bareilly and S. typhimurium from chicken feed. Wilson (1948) considered dried egg powder, unfit for human consumption and used in feed stuffs, a source of Salmonella serotypes introduced into Great Britain.

Erwin (1955) recovered S. oranienburg from three of 206 poultry feed samples. Boyer et al. (1962) found six Salmonella serotypes in five turkey starter mash samplings; however, no Salmonellae were recovered from samples of feed for chickens or ducks. Morehouse and Wedman (1961) cited ten domestic and foreign reports in which Salmonellae were found in animal by-products used for poultry rations. They also cited six references in which contaminated feed sacks may have been disseminators of Salmonellae. In their survey, Salmonellae were recovered from 5% of 403 samples of poultry feed.

Walker et al. (1961) found Salmonellae in 9% of raw ingredients, in 2.8% of finished meal, and in 0.27% of pelleted feed from 4,140 samples of raw ingredients and complete feeds. Morehouse and Wedman (1961) reported that of 59 serotypes recovered from 718 positive samples of animal by-products, S. montevideo, S. senftenberg, S. typhimurium, S. cubana, S. infantis, and S. oranienburg were the types most frequently encountered. Recontamination after processing was believed to be the principal factor accounting for Salmonellae in these products. Meat scraps, meat scraps and bone meal, and poultry by-products were positive for Salmonellae in 32%, 26%, and 33% of the samples, respectively. In the study by Boyer et al. (1962), several Salmonellae were isolated from samples of meat scraps while none were isolated from fish meal. Watkins et al. (1959) isolated 28 serotypes from 37 of 200 samples (18.5%) of poultry feed and animal by-products used in feeds. Pomeroy and Grady (1961) recovered 42 Salmonella serotypes in 175 of 980 samples (18%) of animal by-products used in feeds. They did not find Salmonellae in the

freshly cooked by-products, and it appeared that these organisms were introduced as a result of recontamination of the cooked product in the processing plant. The majority of the samples were contaminated by more than one serotype. Burr and Helmboldt (1962) isolated Salmonellae from an average of 12.8% of 436 samples of fish meal, meat scraps, and poultry by-products. In an examination of meat meal samples imported from the United States, Galbraith et al. (1962) recovered 15 serotypes from 11 of 17 samples.

In regard to recontamination of rendered meals, Magwood et al. (1965) did not recover Salmonellae after the melting and the expelling processes, but they isolated these organisms from nine of 36 samples after grinding. In three plants the product was stored before and after the grinding in heaps on the floor. Salmonellae were recovered from 18 of 36 samples taken from ledges and from the floor at the margin of these storage heaps.

Morehouse and Wedman (1961) mentioned nine reports in which Salmonella infections in poultry, livestock, and laboratory animals were either traced to, or associated with, rations. For instance, Griffin (1952) reported that S. newport was isolated from feed following an outbreak in laboratory animals. Outbreaks of S. thomasville and S. taksony infections in poults associated with the consumption of contaminated feed were cited by Boyer et al. (1962).

### Water

Gauger and Greaves (1946c) demonstrated that contaminated drinking water could serve as a source of disease in a contaminated environment.

Residual drinking water at the end of 24 hours in a pen housing artificially infected turkeys was sampled at biweekly intervals over a period of nine weeks. S. typhimurium was recovered on 13 of the first 14 biweekly tests. During this period the drinking container was scrubbed, rinsed several times, and filled with fresh tap water daily. Subsequently, when the drinking container was scalded daily, S. typhimurium was not found during five biweekly tests.

Buxton (1957) commented that the effect of water on the viability of Salmonellae depends on the sun's rays, the amount of dissolved oxygen in the water, carbon dioxide in the air, the pH, and the temperature. Orr and Moore (1953) noted that S. gallinarum was viable in distilled water stored in diffused light and at room temperature for 88 days, up to the time the water evaporated. In Australia, Watts and Wall (1952) observed that S. typhimurium could survive in ponds for at least 119 days.

### Vectors

Salmonellae have been isolated from various insects, including flies, fleas, ticks, and cockroaches. Ostrolenk and Welch (1942a,b) have shown that flies artificially contaminated with S. enteritidis carried this organism their entire life and were capable of depositing large numbers of Salmonellae on food by defecation and regurgitation. S. enteritidis also survived during the metamorphosis of the fly. Infection was transferred from flies to mice and from mice to flies. McNeil and Hinshaw (1944) recovered S. typhimurium from flies trapped on turkey ranches. Gwatkin and Mitchell (1944) isolated S. pullorum from chicks that had been exposed to infected flies and from feed contaminated by flies. S. pullorum was found

on the feet and wings of the flies for at least six hours after exposure, and this serotype was not recovered from the gastrointestinal tract for at least five days. In high endemic areas of shigellosis, Watt and Lindsay (1948) proved that flies were a source in the spread of shigellosis, but they failed to demonstrate the role of flies in the spread of salmonellosis. Steinhouse (1947) lists six Salmonella serotypes isolated from flies. Greenberg et al. (1963) found 20 to 66% of pooled fly samples positive for Salmonellae in a Mexican abattoir with large populations of flies and rats. Four serotypes were isolated from flies trapped on offal or manure. Buxton (1957) mentioned that ticks may remain carriers of Salmonellae for more than 30 days after oral infection. Eskey et al. (1949) isolated S. enteritidis from fleas in a mouse colony. Olson and Rueger (1950) observed that S. oranienburg survived for 10 to 20 days on three common species of household cockroaches. Salmonellae were excreted in the roaches' feces, and the fecal pellets remained infective for a period of 199 days at room temperature.

Tradition holds that rats and mice are important in the spread of salmonellosis in man or turkeys, but the evidence is circumstantial. Domestic rodents are victims of their environment; however, once contaminated they could serve to perpetuate Salmonellae. Welch et al. (1941) reviewed surveys of rat populations in which the Salmonella incidence ranged from 0.7 to 13%. They surveyed 420 rats from 37 states and found a Salmonella incidence of 1.2%. They also found that Salmonellae remained viable for 148 days in rat feces. Greenberg et al. (1963) observed infection rates of 27.5% in rats at a Mexican abattoir.

Hinshaw and McNeil (1951) reported that Salmonellae have been found

in snakes, lizards, and tortoises, and that they frequent the areas where poultry are kept. Williams (1959) stated that pigeons, sparrows, and other wild birds may serve as sources of infection to poultry flocks. Belding (1955) recovered S. pullorum from five of 65 wild pheasants.

#### Other modes of transmission

Adler et al. (1953) demonstrated that poults could be infected with S. typhimurium by the intranasal route. Contaminated down and dust may carry Salmonellae, and these organisms may be inhaled by susceptible poults. Clemmer et al. (1960) infected one to two day old chicks by exposing them to quantitated aerosols of ten strains of Salmonella. The number of organisms necessary to initiate respiratory infection was low, in some cases less than 20. Lung infections occurred as well as concurrent enteric and hematogenous infections.

After artificial infection of poults, Adler et al. (1953) recovered S. typhimurium from the dust, litter, and feathers for 71, 44, and 37 days, respectively. Thus, in a contaminated environment, the disease may be transmitted via mechanical means where litter and feces adhere to footwear, feed bags, shipping crates, or brooding equipment. Contaminated egg shells and debris of the hatch may serve as a source of infection in an incubator. Miura et al. (1964) isolated Salmonellae from 52.7% of 300 "chicken-hatcher fluff" samples.

Van Es and Olney (1940) subjected two groups of chickens to good and poor sanitation and observed the losses due to fowl typhoid after infected fowls were placed together with healthy birds. In the sanitary lot, the yard was covered with gravel, the house floors were constructed with wire,

the water fountains were self-cleaning, and the feeders were covered as much as possible. In the insanitary pen, the yard was dirt and ungraded, and the water and food vessels were open. Seventy birds died of fowl typhoid in the insanitary lot, while only ten birds died in the sanitary lot.

Hinshaw et al. (1944) recorded instances in which humans transmitted salmonellosis to poults. They also reported that S. panama and S. montevideo were transmitted to man as a result of handling infected poults. Hinshaw and McNeil (1948 and 1951) recorded seven cases of gastroenteritis among poultry caretakers resulting from contact during outbreaks of salmonellosis in fowl. Browne (1949) reviewed a human case of S. anatum in a caretaker following an outbreak due to this organism in a flock. Easter chicks have transmitted salmonellosis to children on a number of occasions (Anderson et al., 1955; and McCroan, 1963).

#### Modes of Dissemination of Salmonellae in Processing Plants

From the preceding review it has been established that poultry are frequently infected with Salmonellae, and that they may be contaminated from a variety of sources during production. Thus, they often come to processing plants harboring Salmonellae. Once in the plant, Salmonellae may be transferred from bird to bird directly or by contact with the environment.

#### Scalding and picking operations

Browne (1949) isolated S. typhimurium from the loading platform, scald chute, and from the floor beyond the scalding in a plant receiving

tom turkeys from a flock which had a history of surviving an outbreak of S. typhimurium. No Salmonellae were recovered from fresh wash water, scald water (53.9°C), floor immediately preceding the scalding, body feather picker, or the scalding conveyor belt. Twenty rectal swabs from the birds were also negative. From another flock with a history of paratyphoid infection, S. typhimurium was isolated from the loading platform, floor of the killing area, floor preceding and following the scalding, floor under the end of line where birds were racked, scalding, entrance chute, feather pile after scalding, body picking machine, and from 32% of cloacal swabs taken from New York dressed birds. No S. typhimurium was isolated from scald water and final wash water. When a flock without a history of salmonellosis passed through the plant, no Salmonellae were isolated from similar swab samples. In another flock with a history of salmonellosis, the above mentioned sources as well as dust from trusses supporting an endless chain were sampled, and S. typhimurium was isolated from each side of the body picking machine and from dust on the truss. Processing continued for another month, with no known infected flocks passing through the plant, and Salmonellae were not isolated. Then a flock which had previously experienced an outbreak caused by S. typhimurium entered the plant. This organism was isolated from the final wash trough, floor of the killing area, floor at the end of the body defeathering machines, floor at the wing picking machine, and rafters above the killing and defeathering machine. From a flock suspected by the owner of suffering from salmonellosis but not confirmed in the laboratory, no Salmonellae were isolated from floor areas, equipment, or bird rectal swabs.

Galton et al. (1955) recovered Salmonellae from 80% of 20 samples



taken from a defeathering machine in a duck processing plant. One hundred twenty-six of 507 (24.8%) cloacal swabs taken immediately after defeathering yielded Salmonellae. Morris and Ayres (1960) isolated Salmonellae from the surfaces of 12% of 50 turkeys after picking and 2% of 50 turkeys after pinning. Salmonellae were not recovered from scald tank water. Hobbs et al. (1960) did not recover Salmonellae from scald water (53°C). Dixon and Pooley (1961) reported no recoveries of Salmonellae from 41 samples of water from scald tanks (53°C or 60°C).

#### Evisceration operations

Sadler et al. (1961) reported on the isolation of Salmonellae from the intestinal tracts of birds upon arrival for slaughter on 30% of 53 sampling days. Multiple flocks were processed on many of the sampling days, and 22% of 94 flocks were positive for Salmonellae. Turkey, chicken fryer, and chicken hen flocks were positive 37%, 18%, and 10% of the time, respectively. Salmonellae were isolated from 2.4% of 2,380 turkey intestines sampled. They were also isolated from 2.6% of 811 chicken fryers and from 1.2% of 519 chicken hens. In examining the viscera and muscle of 129 healthy broilers received for slaughter, Galton et al. (1955) did not recover Salmonellae.

Schneider and Gunderson (1949) reported that immediately after evisceration 13 of 362 samples from the skin of chickens were positive for two serotypes of Salmonella, whereas after chilling and just before packaging, 21 of 332 samples of the skin of chickens were positive for one serotype. They emphasized that the difference in numbers of Salmonellae recovered after chilling and before packaging was not statistically

significant. They believed that the customary methods of cleaning and washing chickens did not eliminate Salmonellae or materially reduce their numbers. Kyle et al. (1952) isolated Salmonellae from the evisceration line, from the skin of birds ready for storage, from viscera of chickens, and from other items on the evisceration line. Gunderson et al. (1954) failed to isolate Salmonellae from the skin surfaces of 49 samples taken before evisceration and from 44 samples taken after evisceration, but they isolated S. pullorum twice from 60 samples taken just prior to storage. Salmonellae were also isolated from necks, gizzards, gizzard wrap table, and gizzard chute.

Galton et al. (1955) isolated Salmonellae from 196 (16%) of 1,244 swab cultures taken from equipment in the eviscerating and grading environment of three poultry processing plants. Salmonellae were recovered from tables on which oil glands and edible and inedible viscera were removed, where edible viscera were wrapped, and on which chickens were graded. Salmonellae were also found on trays containing edible viscera, saws, chill tanks holding eviscerated chickens, and the gizzard peeler. Of 118 swab samples taken from tanks holding iced chickens, 11% were positive for Salmonellae. These organisms were recovered from rinse waters from many of the above mentioned items of equipment, but usually at a lower rate than from swab samples of the equipment. Salmonellae were isolated from 2.7% of 292 swab samples taken from the skin surface of carcasses at various locations along the processing line, but only 1.9% of 53 cloacal swabs were positive.

In a survey of eight chicken and duck processing plants in Pennsylvania, Brobst et al. (1958) failed to isolate Salmonellae from 263

cloacal swabs taken before or after slaughter; however, 26 of 580 swabs taken from the abdominal cavity of chickens after evisceration were positive. All of the positive swabs were recovered on one day from one plant. S. typhimurium was isolated from three of five chill tanks used for chilling prior to evisceration. Salmonellae were not isolated from defeathering machines, eviscerating tables, rinse tanks used after eviscerating, or ice water storage tanks.

Walker and Ayres (1959) reported that Salmonellae were isolated at one time or another at each of the various stages of processing (after rough pick, after final pick, after pinning, after evisceration, and on the final product); however, no quantitative estimates were made. Morris and Ayres (1960) recovered Salmonellae from 4% of 50 samples taken from the cavity of turkeys after evisceration and from 40% of 50 surface samples taken after the final rinse. Two percent of 50 samples of water from the waste trough were positive. In processed chickens, 23% of 24 samples of carcass surfaces after evisceration, 20% of 30 samples from abdominal cavities after evisceration, and 13% of 30 samples taken after the final rinse were positive for group D Salmonella. Thirty samples each from trough waste water and drainage water from the giblets yielded Salmonellae 23% and 13% of the time, respectively. Hobbs et al. (1960) recovered Salmonellae from slush ice water.

In England, Dixon and Pooley (1961) recovered Salmonellae from 21% of 87 samples of water from chill tanks and from 19% of 60 swabs immersed in chill tanks, despite a continuous slow flow of water through one tank and the occasional addition of a hypochlorite solution to the other tank. Salmonellae were also isolated from 30% of the swabs taken from eviscerated

carcasses and from 3% of the swabs taken from edible viscera. Later, Dixon and Pooley (1962) studied two turkey processing plants. They isolated Salmonellae from 18% of 146 abdominal cavity swabs of turkeys. From 4-5% of the swabs taken from evisceration troughs, giblet troughs, giblets, chill tanks, rinsing waters, and drains were also found to be positive for Salmonellae.

Salzer (1964) isolated Salmonellae from 29 of 300 samples of unwashed giblets and from 16 of 300 samples of washed giblets. The majority of these isolations were recovered from a single flock which was processed in one plant.

#### Human carriers

Browne (1949), Kyle et al. (1952), Gunderson et al. (1954), and Dixon and Pooley (1961) isolated Salmonellae from the hands or gloves of workers on the evisceration line. Gunderson et al. (1954) swabbed the hands of the employee who cut about the thighs and vents, of the eviscerator who manually removed the viscera, of the veterinary inspector, and of the worker who rehung the birds after the inside wash. Twenty-two samples were taken from each worker. The inciser was positive 9.1%, the eviscerator 13.6%, the inspector 31.8%, and the worker 9.1% of the time. Thus, 15.9% of 88 samples from workers' hands were positive for S. pullorum, the only serotype found.

In an examination of nearly ten thousand apparently healthy people from England, Savage (1956) found 0.24% were carriers of Salmonellae. Saphra and Winter (1957) in Massachusetts estimated the carrier rate in the general population to be 0.2%. Among 2,000 hospital workers and

patients, Felsen et al. (1950) found a carrier rate of 0.25%. Typing laboratories have reported a fairly high percentage of isolations from asymptomatic persons. For example, Seligmann et al. (1943) reported 10%, Edwards et al. (1948b) reported 30%, MacCready et al. (1957) reported 21%, Saphra and Winter (1957) reported 15.5%, and Galton and Hardy (1953) reported 63%. Many of the cultures isolated by Galton and Hardy (1953) were obtained from food handlers. Stone (1943) reported that 2.2% of 2,000 Army food handlers were carriers of Salmonellae.

In an investigation reported by McCroan (1963), there were indications that workers contracted the infection from chicken meat and then were instrumental in maintaining the infection in the plant environment. Felsenfeld and Young (1949), in reviewing the literature, found that 26 of 56 outbreaks of salmonellosis caused by non-host adapted serotypes were traced to human carriers. Thompson (1955) indicated the importance of the carrier as a disseminator of Salmonellae; he found that the numbers of organisms excreted by asymptomatic carriers vary widely, but that the number per gram of feces sometimes exceeded those found in clinical cases.

In studies of human volunteers, McCullough and Eisele (1951a,b,c,d) have shown that individuals without clinical signs of salmonellosis excreted S. meleagridis, S. anatum, and S. derby for 128, 107, and 44 days, respectively.

#### Plant surveys

A few poultry processing plant surveys have been carried out by various investigators (Galton et al., 1955; Morris and Ayres, 1960;

and Dixon and Pooley, 1961 and 1962).

Galton et al. (1955) reported on the results of 48 surveys made in three chicken processing plants at intervals of one to five weeks. Swabs were taken of carcasses and the plant environment. Of 517 samples from Plant A, 16.6% were positive for Salmonellae; of 486 samples from Plant B, 19.9% were positive; and of 241 samples from Plant C, 5.3% were positive. In a duck processing plant, 25% of cloacal and environmental swabs were positive for Salmonellae.

Morris and Ayres (1960) reported that 2.4% of 500 samples of carcass surfaces and process water were positive for Salmonellae in a turkey processing plant. They also recovered 28 Salmonellae from approximately 300 similar samples taken in a chicken processing plant.

In England, Dixon and Pooley (1961) made visits to a chicken processing plant and recovered Salmonellae from 13.8% of 544 samples from carcasses, edible viscera, process water, and workers' hands. Salmonella were isolated on 13 of 23 visits. Subsequently, they (1962) isolated Salmonellae from 10 of 21 and from 8 of 27 visits to two turkey processing plants. Swabs were taken of carcasses, environment, process water, and sewers. In one plant, a single phage type of S. typhimurium was found on 19.2% of 187 samples taken, whereas in the other plant, three phage types of S. typhimurium and two other Salmonella serotypes were isolated from 7.7% of 129 samples.

Presence of Salmonellae on Poultry Meat

The presence of Salmonellae in dressed poultry is evident from several reports. Cherry et al. (1946) isolated a non-motile Salmonella from frozen turkeys. Browne (1949) reported that two swab samples of 15 taken from the skin of frozen eviscerated turkeys originating from a flock having a history of Salmonella infection were positive for Salmonellae. Schneider and Gunderson (1949) found four serotypes of Salmonellae on the skin of 4.4% of 1,014 eviscerated chickens. Most of these birds had been frozen for some time. Felsenfeld and Young (1949) reported that 1.2% of 500 U.S. inspected birds and 9.2% of 500 uninspected birds were positive for Salmonellae. Salmonellae were present in only 2% of 50 inspected birds and in 14% of 50 uninspected birds in Puerto Rico. Similarly, in a survey of retail market meat, Felsenfeld et al. (1950) recovered Salmonellae from 0.9% of 372 U.S. inspected and passed birds. Salmonellae were recovered from 10.8% of 748 uninspected birds. In British Columbia, Tailyour and Avery (1960) isolated Salmonellae from only 0.76% of 523 samples of processed turkeys.

In a study of dressed broiler chickens from retail stores in three Canadian cities, Thatcher and Loit (1961) recovered Salmonellae from 14% of the fresh birds that had not been treated with chlortetracycline. Wilson et al. (1961) recovered Salmonellae from 17% of 525 market poultry samples. Woodburn (1964) isolated Salmonellae (13 serotypes) from 27% of 264 dressed fryer chickens.

### Survival of Salmonellae

The foregoing information has shown that Salmonellae have been frequently found in fowl, on poultry products, and in the farm and plant environment. Although there are a few reports on survival of Salmonellae on turkey products and in processing plants, analogies can be made from the survival of Salmonellae on other food products and on various environmental surfaces.

#### On surfaces

S. gallinarum survived in the dark at room temperature on cloth for 228 days, and on plastic cover slips for 93 days (Orr and Moore, 1953). Felsenfeld and Young (1945) have shown that Salmonellae survived on vegetables kept at room temperature for several weeks. In Australia, Watts and Wall (1952) reported that contaminated earth remained contaminated at least 200 days. Pomeroy and Fenstermacher (1939) found that Salmonellae survived on turkey egg shells at incubator temperatures for at least 11 months, at 10°C for 191 to 349 days, and on exposure to the elements for 135 to 350 days. Buxton and Gordon (1947) observed that S. thompson could survive on the surface of chicken eggs for at least 21 days at room temperature. S. typhimurium survived on two of 26 turkey egg shells in an incubator for at least 28 days (Gregory, 1948). Lancaster and Crabb (1953) found that S. typhimurium and S. thompson rapidly lost viability on chicken egg shells stored at incubator temperatures, although they observed survival for 21 days on clean eggs and longer on dirty eggs stored at room temperature. Increased humidity prolonged the viability of Salmonellae.



### In feces

In a study by Pomeroy and Fenstermacher (1939), Salmonellae survived in feces up to 9 days. Smith (1955) found that the average survival time of S. gallinarum in feces from infected chickens was 10.9 days in the range house and 9 days in the open. Survival was longer in naturally dried specimens than in those that were kept moist. In this study, long periods of dry weather appeared to favor survival times.

### In soil, dust, and litter

S. typhimurium remained viable in soil for up to 251 days under ordinary weather conditions (Mair and Ross, 1960). Browne (1949) observed that S. pullorum and S. gallinarum disappeared from old built-up litter more rapidly than they did from new cob litter, and a higher mortality rate due to S. gallinarum occurred in the chicks on the new litter. According to Miura et al. (1964), "hatcher fluff" kept 1-4 years at room temperature still gave  $10^4$  to  $10^6$  viable Salmonellae per gram.

### Under the influence of antibiotics

Since Salmonellae may multiply more rapidly than normal spoilage organisms on poultry treated with antibiotics, Barnes (1957) warned that the public health problem was associated with the emergence of Salmonellae resistant to antibiotics. Thus, visible signs of spoilage would be delayed, but the food poisoning potential would be present.

The resistance of S. typhimurium to tetracyclines has been reported by Huey and Edwards (1958). None of 200 cultures were reported to have

resistance in 1948, but 9% of those tested were resistant in 1946. Gordon (1959) found that resistant strains of S. typhimurium developed in chicks receiving chlortetracycline in their ration but not in chicks which consumed feed without the antibiotic. During this study, a nine fold increase in resistance from 25 to 225 ppm was noted. A strain of S. typhimurium resistant to chlortetracycline was found by Hobbs et al. (1960) to grow readily on the skin of "acronized" poultry. In fact, they grew more readily than did spoilage organisms. There was also a gradual development of resistance to chlortetracycline in the sensitive strains. The mortality rate was lower in the antibiotic fed chicks than in chicks not receiving the antibiotic, but, on the other hand, more carriers occurred in the antibiotic fed group. Of 627 strains of S. typhimurium isolated from 1957-1959, 1.6% were found to be resistant.

#### Growth potential

Angelotti et al. (1961a) demonstrated that S. senftenberg, S. enteritidis, and S. manhattan were able to multiply in the temperature range between 6.7°C and 62.2°C (44-114°F). Hobbs et al. (1960) observed that S. typhimurium grew rapidly at 15°C (59°F) on the skin of dressed chickens in the presence of a rapidly growing spoilage flora.

#### During freezing

As mentioned previously in this review, Salmonellae have been isolated from frozen poultry products on a number of occasions. Studies relating to the survival of specific serotypes have been made, and some of the more pertinent are reviewed.

Prucha and Brannon (1926), Wallace and Park (1933), McCleskey and Christopher (1941) have found that Salmonellae can survive on food products which were subjected to frozen storage for several months. S. gallinarum has been reported to survive in distilled water after daily freezing and thawing for as long as 43 days (Orr and Moore, 1953). Woodburn and Strong (1960) froze S. typhimurium in five simple food substrates and stored these for ten weeks at  $-11^{\circ}\text{C}$ ,  $-21^{\circ}\text{C}$ , and  $-30^{\circ}\text{C}$ . S. typhimurium was recovered after ten weeks of storage at all temperatures in many of the food substrates, and little destruction occurred in the samples stored at the lowest temperature.

In regard to survival of Salmonellae in frozen poultry, Gunderson and Rose (1948) showed that there was a rather rapid initial decline in numbers of large inocula of six serotypes of Salmonellae (S. newington, S. typhimurium, S. typhi, S. gallinarum, S. anatum, and S. paratyphi B) with 33-92% killed by the fourteenth day in chicken chow mein stored at  $-25^{\circ}\text{C}$ . The subsequent decline was slow. After 270 days, at least 86,000 Salmonellae still remained. S. typhimurium appeared to survive somewhat better than the other serotypes, and 20% survived storage for nine months.

Thirty-four of 694 (4.9%) skin samples from fresh chilled chickens were found to be positive for Salmonellae in a study conducted by Schneider and Gunderson (1949), whereas in only 15 of 2586 (0.6%) skin samples from frozen storage chickens were Salmonellae isolated. The statistical difference between the fresh chilled and the frozen chickens was highly significant in this study. Browne (1949) recovered S. typhimurium on the skin of frozen turkeys after 13 months' storage. Orr and Moore (1953) observed that S. gallinarum in a naturally infected liver survived storage

at 7°C for only two weeks and survived storage at -20°C for at least 148 days. Pathogenicity was retained after this prolonged frozen storage temperature. Starting with initial low levels of Salmonellae (<1-4.5 organisms per cm<sup>2</sup>) Kraft et al. (1963) were able to detect these organisms in low concentration (<1 organism per cm<sup>2</sup>) after freezing and after storing turkeys at -29°C for 13 and 30 days.

#### Thermal destruction

According to regulations of the United States Department of Agriculture, Agricultural Marketing Service (1963), cured and smoked poultry rolls should reach an internal temperature of at least 68.3°C (155°F). They (1964) also require that all other poultry rolls should reach an internal temperature of at least 71.1°C (160°F) prior to being removed from the cooking media. This conclusion was supported by a study of Wilkinson et al. (1965) in which no viable Salmonellae were found in rolls inoculated and oven cooked to temperatures of 65.6°C (150°F) or higher. Streptococci were killed at temperatures of 71.1°C (160°F) or higher. Wiedeman et al. (1956) cooked inoculated ham loaves and observed that enterococci and Salmonellae were destroyed when the loaves reached an internal temperature of 71.1°C (160°F). After making heat penetration determinations during the baking of 24 household foods in which dried eggs were used as an ingredient, Beloian and Schlosser (1963) concluded that a temperature of 71.1°C (160°F) or higher in the slowest heating region was sufficient to free the foods from viable Salmonellae.

Adequate roasting procedures for poultry were considered by Esselen et al. (1956) to be those providing at least the equivalent of a center

temperature of 71.1°C (160°F) for 10 minutes ( $z = 14^\circ\text{F}$ ). These investigators suggested a center temperature of 73.9°C (165°F) for birds less than 12 pounds. For larger birds, a center temperature of 68.3°C (155°F) was suggested since there would be a slower rate of heat penetration and, therefore, longer periods at lethal temperatures.

The Food Service Sanitation Manual of the U.S. Department of Health, Education, and Welfare, Public Health Service, (1962) which is a recommended ordinance and code for food-service establishments, stipulates that stuffing, poultry, and stuffed meats and poultry should be heated throughout to a minimum temperature of 73.9°C (165°F) with no interruption of the initial cooking process. In a study by Castellani et al. (1963), conclusions were formed that a temperature of 73.9°C (165°F) in the center of stuffing during roasting appeared sufficient to kill inoculated enterococci, staphylococci, and Salmonellae and to allow a modest margin of safety. Rogers and Gunderson (1958) found that a temperature of 71.1°C (160°F) must be reached in the center of the stuffing to assure adequate destruction of S. pullorum, and to allow a modest margin of safety they suggested a minimum temperature of 73.9°C (165°F).

Angelotti et al. (1961a) contaminated custard, ham salad, and chicken a la king with ten million Salmonellae or staphylococci per gram, and when these products were heated to 65.6°C (150°F) and held at this temperature for at least 12 minutes, the organisms were reduced to nondetectable levels. The same level of destruction was reached for these foods with 60°C (140°F) when they were held for at least 83 minutes. Anellis (1954) showed that S. senftenberg (775W) had a  $F_{140}$  value as high as 88.75 minutes and a  $z$  value of 11.95°F at pH 6.1.

In a study conducted by Bayne et al. (1964),  $3 \times 10^8$  cells of S. typhimurium gave a negative test for viable cells when heated 5 minutes at 50°C, whereas  $10^8$  cells of S. senftenberg 775W required 10 to 15 minutes heating at 65°C before negative tests were obtained.

Contrary to the studies of thermal destruction of Salmonellae at or below 73.9°C (165°F), Hussemann and Wallace (1951) found that, with currently accepted methods of broiling or roasting chicken, the number of Salmonellae in muscle and liver were markedly reduced but in no case was the chicken rendered free from Salmonellae. However, no Salmonellae were isolated from 280 samples of cooked fowl collected from public eating establishments. They attributed the negative results to adequate cooking or to use of chickens free from Salmonellae. In reviewing this study, Dack (1956) commented that the subsequent negative results indicated that the experimental test with chickens intravenously injected with high numbers of Salmonellae was perhaps too severe to approximate naturally occurring Salmonellae contamination of poultry meat.

## MATERIALS AND METHODS

## Plant Operations

Product definitions and manufacturing techniques

When an eviscerated turkey is boned or segments cut from it, these portions become known as "further processed" turkey products. Since "further processed" poultry products are not all legally defined and are manufactured by different procedures throughout the country, it seems in order to describe the products studied during this investigation as well as their methods of preparation.

Chilled, eviscerated carcasses This term refers to turkeys which have been processed to the point of feather removal, feet and head removal, and evisceration. Furthermore, they have been chilled to a temperature of 4.4°C (40°F) or lower by overnight storage in a chill tank containing slush ice. These turkeys are ready for packaging as whole birds or for "further processing" operations.

Cooked, ready-to-eat, turkey rolls Turkey rolls are manufactured in a number of ways, and a variety of vastly different products are labeled as turkey rolls. For instance, Forward and Joule (1955) listed eight different types of turkey rolls processed in Missouri. Throughout the country, variation is noted in the size, weight, shape, appearance, packaging, and method of cooking. In regard to differences in processing, Botsford (1950) described a process for making turkey rolls wherein carcasses were skinned and boned. Then the meat was replaced in the skin and the skin sewed together. Next, the roll was roasted at a low temperature until a brown crackly glaze was produced over the skin. Dawson

(1964) described rolls which were formed, placed in aluminum foil, and cooked in ovens at a low temperature (200-250°F). After the rolls were cooked, they were drained of excess juice and placed in shrinkable plastic bags, sealed, chilled in ice, and frozen. Some rolls were cooked in ham presses, and others were cooked in smokehouses after pre-cooking (Dawson, 1964).

The rolls studied in this investigation were fabricated and cooked in a different manner. They consisted of 50-60% white meat, with the remaining portion dark meat, although rolls consisting of white meat only were also made. Binding agents, such as gelatin, were added in quantities not in excess of a total of 3%. Salt and monosodium glutamate were also added. The final weight was approximately 9 pounds, although one plant manufactured a 2 1/2 pound roll.

Breast and thigh portions were boned from the chilled, eviscerated carcasses. Weighed portions of white meat were placed in a cylindrical roll shell. Binding agents and seasonings were sprinkled in measured amounts on the surface of the meat, and dark meat added. Next, a water-soaked, plastic casing, which had been fastened with a metal clamp on one end, was pulled over the roll shell and the meat. The casing, containing meat, was slid from the shell. The bag was tamped on the enclosed end until a uniform fill was obtained. The open end was twisted, drawn tight, and fastened with a metal clamp. The rolls were placed in a tank containing slush ice. When quantities sufficient to fill the cookers were prepared, the rolls were loaded on a metal rack, hoisted, and immersed in a tank of steam-heated water. The water bath temperatures ranged from 73.9°C (165°F) to 84.4°C (184°F) for 4 hours and 15 minutes to 5 hours and



30 minutes, depending on plant procedures. An internal temperature of 71.1°C (160°F) must be reached to comply with regulations of the United States Department of Agriculture (1964). After the rolls were cooked, they were removed and cooled in a vat containing running tap water or in a tank containing slush ice. At one plant, the upper portion of the bag was pierced to drain the excess juice, and then the casings were redrawn and reclamped. Next, the rolls were subjected to blast freezing. Rolls were removed from the freezer, boxed, and placed in frozen storage until they were shipped.

Uncooked, frozen turkey rolls As with the cooked turkey rolls, uncooked rolls are manufactured in different forms, although only one type was made by the plants studied in this investigation. The process was similar to that employed for the preparation of the cooked rolls; however, no heat treatment was applied. Twelve pounds of turkey meat (from which bones and tendons had been removed) from all of the turkey segments except the wings were formed in large rectangular pans. Seasonings were added. Then the rolls were tied with twine and wrapped in aluminum foil. Next, they were placed in a plastic bag, boxed, weighed, and frozen.

Turkey logs Turkey logs consisted of white and dark seasoned meat wrapped in skin. The final weight was approximately 9 pounds. Turkey logs were made only in one plant, and Richey (1957) described the process of manufacture as follows: Cylindrical, two-part, steel molds which measured about 15 inches long by 4 1/2 inches in diameter were used in the preparation of this product. Chilled, eviscerated carcasses were boned and skinned. One part of the mold was lined with turkey skin, with the skin extending over the edge. White meat (60%) was laid lengthwise into

the mold. Two ounces of seasoning, including sugar, salt, and monosodium glutamate, were added. Next, dark meat was added in quantities sufficient to complete the roll. More seasoning was added and the skin was folded up over the meat. The upper half of the mold was fitted into place, and wood wedges were applied to compress the meat. The filled molds were placed in a blast freezer, and when they were frozen, the meat was taken out of the molds. The meat was sometimes quartered with a saw before it was wrapped in foil.

Turkey roasts Roasts consist of 3-5 pound portions of boned turkey meat held together by twine. While several varieties are manufactured, only four types were encountered during this study. Roasts containing approximately 60% breast and 40% thigh meat were manufactured in both plants. These were formed in rectangular pans and then tied by hand or by automatic tying machines. Similar roasts were made up of 51% white meat. In the preparation of these roasts, carcasses were skinned. Weighed portions of meat were formed in pans and a layer of skin placed on top. Next, they were placed in a blast freezer until an ice crust was formed (about 20 minutes). Afterwards, the roasts were tied and a seasoning solution was injected and pumped into them. A third type of roast was made of all dark meat which, after tying, was dipped for several seconds into a solution of reconstituted frozen pineapple juice. Another type consisted of larger amounts of white and dark meat with seasonings added. After the roasts were formed, they were placed in plastic bags. Then a vacuum was applied, and the packaging material was shrunk. Next, the roasts were placed in individual boxes and conveyed to the blast freezer.

Turkey steaks Turkey steaks are individual slices of ground turkey meat cut from a frozen roll 4-5 inches in diameter. In preparing steaks, a portion of turkey meat was coarse ground to form chunks approximately 1 inch in diameter. Chunks were thoroughly mixed in chill tanks with finely ground turkey meat. The mixture was placed in a grinder (without knives) and expelled into plastic sausage casings. The casings were tied, and the rolls were frozen in a blast freezer. After the rolls were solidly frozen, approximately 1/2 inch slabs were cut from the rolls with a band saw. The slices were placed between wax paper, stacked, bagged, boxed, and weighed. The boxes were then placed in frozen storage.

Segments Segments, as the name implies, are the individual parts of the turkey including skin, meat, and bones in their natural conformation. After the segments were cut and weighed, they were placed in a plastic bag and the bag evacuated. Next, the package was shrunk and the product frozen. Breasts were bagged one per package, while drumsticks, wings, and thighs were usually bagged two per package or in bulk.

The pectoralis minor muscle was sometimes individually wrapped or packaged in bulk and were labeled breast filets.

#### Plant descriptions

Two turkey processing plants were surveyed during this investigation. Both were under the supervision of the Agricultural Marketing Service of the United States Department of Agriculture. Their killing operations commenced in May or June and extended until the end of December; however, they sometimes continued for a few weeks thereafter. Occasionally,

eviscerated carcasses were frozen during the killing season and processed in the late winter and spring.

Plant A Plant A processed approximately ten million pounds of turkey annually. Fresh killed turkeys comprise over 75% of this total. A maximum daily capacity was 3,500 turkeys. Practically all of the plant's production consisted of cut-up or processed turkey products, as opposed to packaged whole turkeys. Two widely separated "further processing" operations were located in the same large room in which evisceration was conducted. The room had a concrete floor which was sloped to drain into several long lateral drains. Ceramic tile was used for wall construction to provide splash protection. When evisceration operations had ceased for the day, the workers were employed in the "further processing" lines.

Turkeys were obtained from flocks in Iowa and nearby states. At the dock, the turkeys were removed from the truck cages and hung on shackles suspended from an overhead endless conveyor chain. After the turkeys were conveyed through an electrical stunner, they were killed by a single cut across the neck. Following bleeding, the turkeys were conveyed through a scalding chamber (60°C) for approximately 2 to 2 1/2 minutes. A wetting agent was used in this process. The turkeys then passed through a neck picker, a series of four picking machines, and a hock picker. After mechanical picking, the carcasses were transferred to another conveyor where they were inspected, and pinfeathers were removed. Next, they were singed, spray washed, and the feet removed. Then, the turkeys passed into the eviscerating and processing room. Here the carcasses were eviscerated, inspected, decapitated, and washed. Following

these operations, the eviscerated carcasses were graded and placed in chill tanks containing slush ice.

After chilling overnight, the carcasses were hooked on endless chain conveyors. Then, they passed by workers who made consecutive cuts to remove the desired segments or meat portions. The boned meat dropped on to a conveyor belt where it passed by workers who trimmed and prepared the meat for packaging. Boned meat which was not immediately packaged was placed in chill tanks and ice was added. The segments were packaged, and the roasts and rolls were fabricated as previously discussed.

Plant B Plant B processed approximately 20 million pounds of turkeys annually; however, most of the product was packaged as whole turkeys. The daily processing volume sometimes ran as high as 20,000 turkeys. "Further processed" items made up only a small proportion of the total production. The "further processing" operations were carried out in a separate room, newly constructed and designed for this operation. The floors were made of quarry tile and were sloped to a long central drain running lengthwise across the room. The walls were constructed of ceramic tile. Personnel employed in this room did not work in other areas of the plant. Usually one lot of turkeys was processed daily in this room. The majority of the turkeys processed in this plant were obtained from farms located within a 20 mile radius of the plant.

After turkeys were hung on shackles, they were conveyed through an electric stunner to the killing room. Here, the necks were cut and the birds bled into a trough. After the blood had drained, the turkeys were conveyed into a picking room where they were moved through a scalding chamber (59°C for about 2 1/2 minutes), three picking machines, and an

automatic spiral picker. From this last picker, the turkeys slid down a chute and across a table where a worker rehung the carcasses on shackles. Next, workers removed the remaining pinfeathers. After the carcasses were spray washed and the feet removed, the birds passed into the evisceration room. Following evisceration, inspection, head removal, and washing, the carcasses passed through a series of three continuous spin coolers. They were then graded and placed in chill tanks containing slush ice. After the carcasses were chilled overnight, they were either hung on a conveyor, graded, weighed, and packaged, or they were wheeled into the "further processing" room.

In the "further processing" room, the carcasses were removed from the chill tanks, weighed, and shackled on an overhead conveyor. Workers stationed along the conveyor cut segments or portions of meat from the carcasses. These segments or portions of meat were placed on a conveyor belt where they passed by workers who trimmed or prepared the meat for processing or packaging.

#### Collection of Samples

##### Farm and truck samples

Feed samples were collected at farms supplying turkeys to Plant B. Farm sources included feeds from previously unopened bags, from open bags, from bulk storage tanks, from open bins or carts, and from the housed portion of feeders in the brooder houses and on the range.

Water samples were collected from the water troughs located in brooder houses or on the range. Both feed and water samples were obtained in sterile, pint, or half pint jars.

At the farms, fecal samples were obtained by inserting cotton swabs into approximately six fresh droppings. From truck beds, fecal samples were taken by a similar procedure; however, particular care was taken to obtain material from the center of fresh stools and not to contact the truck bed. The cotton portion of the swab sticks were snapped into a screw cap tube containing 10 ml of tetrathionate broth (BBL)<sup>1</sup>. The tetrathionate solution contained 10 ml of a 1:1000 dilution of brilliant green solution per liter (Edwards and Ewing, 1962).

When turkeys were available which had died the night before, they were placed in a bag and brought back to the laboratory for autopsy and culturing.

#### Plant samples

For the isolation of Salmonellae, swabs moistened in sterile peptone water were rolled over the breast, thigh, and randomly on other areas of the carcasses after picking, washing, spin chilling (Plant B), and overnight chilling. The exposed surfaces of the chilled whole carcasses and the "further processed" products were swabbed just prior to packaging. To obtain random samples from each stage of processing, one sample was taken from the carcasses after picking, then one from carcasses after washing, and one from carcasses before icing. Later, the sample cycle was repeated. In regard to sampling in "further processing" area, a sample was taken from the chilled, eviscerated carcasses, and then a sample was taken from the finished product before returning to the first sample point. By this method of

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<sup>1</sup>Baltimore Biological Laboratories, Baltimore, Maryland.

sampling, no more than two carcasses were sampled from any one chill tank. Areas on large equipment were swabbed randomly at points where carcasses or meat came in contact, whereas the entire contact surface of small items were swabbed. Swabs were put into tubes containing tetrathionate broth.

For the evaluation of total numbers of coliforms, enterococci, and aerobic organisms, 10 cm<sup>2</sup> areas from breast or thigh portions of chilled, eviscerated carcasses and from exposed surface of the finished products were swabbed. After a sterile metal template was placed on the surface of the meat, a moistened swab was firmly rubbed over the encircled area, reversing the direction at right angles three times. The swabs were snapped into tubes containing 10 ml of a 0.1% peptone water (Difco)<sup>1</sup>, and the tubes were iced for transportation to the laboratory.

Cooked turkey roll samples were obtained from two sources. They were purchased after cooking from the plants, and they were procured prior to food service preparation from a State institution. The turkey rolls from the plants were chilled and returned intact in their casings to the laboratory. The turkey rolls obtained from the institution were cut in half while still in a partially frozen condition. Another sterile knife was used to cut a thin slice of meat from the bisected roll. A sample of approximately 100 grams was cut from the center of the roll and placed into a sterile, pint jar. Both white and dark meat portions were sampled. Between samples, sampling implements and knives were immersed in alcohol and flamed twice before reuse.

Occasionally, turkey products were purchased from the plants and brought to the laboratory while frozen in their original packages.

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<sup>1</sup>Difco Laboratories, Detroit, Michigan.



Rinse samples from workers' hands were collected in sterile, five-pound capacity, paper cartons. In preparing the containers for field use, a test tube brush was placed in the carton which was then covered and sterilized. Workers were selected at various points along the processing lines, and requested to pour approximately 50 ml of sterile lactose broth (Difco) over one hand so the drippings would run into the open container. Next, they scrubbed their finger nails, back of hand, palm, and fingers with the brush for approximately 1/2 minute and repeated this procedure with the other hand. The hands were then wrung and the drippings allowed to fall into the container. Rubber gloves were sampled in a similar manner. The brush was placed in the carton, and the carton was covered and secured. Wire mesh gloves were placed in a carton and lactose broth added. The fluid was swirled around the glove and the glove brushed. In this case, the brush was not enclosed in the carton.

#### Microbiological Laboratory Procedures

##### Isolation of Salmonellae

Pre-enrichment and enrichment of swab samples At the laboratory, the tetrathionate tubes were tapped against the palm of the hand 50 times to mix the sample and loosen the cotton. Then the tubes were incubated at 37°C for 24 hours, streaked, and reincubated another 24 hours.

Two 30 gram samples of feed were aseptically weighed in sterile jars. One hundred ml of tetrathionate were added to one sample, and 100 ml of lactose broth were added to the other sample. The lids were tightened,

and the jars were vigorously shaken. After an hour, the jars were shaken again. Following incubation at 37°C for 24 hours in lactose, the jars were shaken, and 1 ml of broth was transferred to tubes containing 10 ml of tetrathionate broth. Tetrathionate jars and tubes were incubated as described. The methods used essentially followed the procedures outlined by Galton et al. (1964a). The use of lactose pre-enrichment has been reported by North (1961). He pointed out its value for the restoration of Salmonellae to a state of active growth in testing dried or frozen foods. In summarizing information concerning enrichment broths, Edwards and Ewing (1962) stated that the choice is dictated by the circumstances under which one is working, but they extolled on the virtues of tetrathionate broth for the isolation of Salmonellae other than S. typhi.

Turkey roll meat samples were handled in a manner similar to that used for feed samples, except that instead of being shaken they were blended for 2 minutes in a blender jar.

Dead turkeys were sprinkled with a quaternary ammonium compound and the viscera aseptically exposed. Portions of the liver and portions of the intestinal tract (in the case of turkeys only a few weeks old, all of the liver and intestinal tract) were placed into sterile blender jars. One hundred ml of tetrathionate broth was added. After blending, the samples were incubated as described.

Hand rinse samples in the covered cartons were swirled 25 times; the direction was reversed, and the cartons were swirled an additional 25 times. Next, the samples were incubated for 24 hours, mixed, and 1 ml was transferred to tetrathionate broth which was handled as previously described.

Plating and screening After incubation, tetrathionate broth tubes or jars were shaken, and a generous loopful (5 mm diameter) of broth was streaked onto brilliant green agar (Difco or BBL) plates. Edwards and Ewing (1962) and Galton et al. (1964a), after reviewing the literature and evaluating their own experience, have stated that the plating of enrichment media inoculated with clinical specimens or foods on brilliant green agar yielded a greater number of Salmonellae, other than S. typhi, than when these samples were plated on other selective media. The brilliant green agar plates were incubated at 37°C for 24 hours.

Three colonies typical of Salmonella were picked from each plate where suspect colonies were observed. They were inoculated into triple sugar iron agar (Difco) slants, and these slants were incubated for 24 hours at 37°C. Since tetrathionate tubes or jars were incubated for both 24 and 48 hours and each plated, approximately six colonies were picked from each sample demonstrating suspect colonies.

When doubtful reactions occurred on triple sugar iron agar, cultures were inoculated into lysine iron agar slants (Edwards and Fife, 1961). Occasionally, other biochemical tests were used. Methods employed followed the procedures outlined by Edwards and Ewing (1962).

Serology Cultures showing reactions characteristic of Salmonella in triple sugar iron agar tubes were subjected to serological examinations. Growth from the culture was emulsified in a drop of polyvalent H serum (CDC)<sup>1</sup> and into five group O sera (B, C<sub>1</sub>, C<sub>2</sub>, D, E<sub>1</sub>). When necessary,

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<sup>1</sup> Communicable Disease Center, Atlanta, Georgia.

other sera were used. Those cultures showing positive agglutinations were inoculated into 4 ml of H broth and incubated overnight at 37°C. An equal volume of 1N NaCl containing 0.6% formalin was added the next day. The tubes were mixed and allowed to stand for an hour. One ml of this mixture was pipetted into each of seven agglutination tubes, and a drop of one of the Spicer-Edwards pooled H sera (pool 1,2,3,4, L complex, en complex, and 1 complex) was added to each tube. The tubes were shaken and incubated in a water bath at 50°C for an hour. Tube agglutination patterns were read and interpreted according to tables by Edwards (1962). After O and H serological groups were determined, cultures were submitted to the Veterinary Public Health Laboratory, Communicable Disease Center, Atlanta, Georgia, for definitive serological identifications.

#### Enumerations

The most probable number of Salmonellae was determined in a laboratory cooking study of turkey rolls. Prior to cooking and after contamination with S. senftenberg (described in a later section) areas of 10 cm<sup>2</sup> were swabbed. The swabs were placed in tubes containing 10 ml peptone solution. After mixing, 1 ml was transferred to three tubes containing 10 ml of lactose broth. Appropriate dilutions were made, and these were also inoculated into lactose broth. After the turkey rolls were cooked, the same procedure was used; however, an additional 30 grams of cooked turkey meat were placed into a sterile blender jar. Then 270 ml of lactose broth were added, and the mixture was blended for 2 minutes. Ten ml, 1.0 ml, and 0.1 ml of the food homogenates and appropriate dilutions were transferred to lactose broth. These were incubated for 48

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hours at 37°C. Selective enrichment, plating, screening, and confirmation were conducted in the manner previously described. This procedure was similar to that described by North (1961) and Galton et al. (1964a).

Coliform, enterococci, and total aerobic determinations were made on chilled, eviscerated carcasses and on the finished product as well as on cooked turkey rolls. Thirty grams of turkey roll meat were blended with 270 ml of peptone water. One ml or 0.1 ml of the mixed solutions or of appropriate dilutions thereof were added to each of duplicate petri dishes. Five ml, 1 ml, and 0.1 ml of turkey roll homogenate were plated in duplicate plates.

For the determination of coliforms, violet red bile agar (Difco) was employed according to the method outlined by Hall (1964a). Dark red colonies with a diameter of 0.5 mm or more were counted.

For enterococci, KF streptococcus agar (Difco) was used, and the procedures outlined by Hall (1964b) were followed. Dark red colonies having a red or pink center were counted.

For total aerobic organisms, mixing and decimal dilutions were prepared as discussed. These counts were made on trypticase soy agar (BBL), using duplicate plates incubated for 48 hours at 30°C. The procedures, other than the medium and incubation temperature, followed those of Angelotti (1964). Colonies were selected and counted as stipulated by the American Public Health Association (1960).

## Temperature Recordings of Turkey Roll Cooking Operations

A Brown recording potentiometer<sup>1</sup>, model No. KY153X84-CS-II-III-(142), was used both for laboratory and for plant evaluations. Recordings were made on Chart No. 5187, -51.1°C (-60°F) to 293.3°C (560°F), type J<sup>1</sup>. Temperatures were taken with iron-constantan leads terminated with two inch long needles<sup>2</sup>.

### Laboratory evaluations

Laboratory cooking studies were conducted to evaluate the thermal destruction of Salmonellae in turkey rolls. After frozen rolls were thawed at 4°C, they were parted in their original proportions. Approximately 500 ml of a 24-hour nutrient broth culture of S. senftenberg 775W<sup>3</sup> was placed in a sterile, shallow pan. The meat segments were dipped into and rotated in the broth so that all the exposed surfaces were contaminated. The meat was removed to another sterile pan and more broth culture added to the first pan and the meat dipped again and rotated. The meat was removed and allowed to drain. After a short drying period, areas were swabbed as described previously for obtaining the most probable number of S. senftenberg. Sterile gloves were used for repacking the

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<sup>1</sup>Minneapolis-Honeywell Regulator Company, Philadelphia, Pennsylvania.

<sup>2</sup>Physics Department, Instrument Shop, Iowa State University of Science and Technology, Ames, Iowa.

<sup>3</sup>Food and Milk Research Program, Robert A. Taft Sanitary Engineering Center, Public Health Service, Department of Health, Education, and Welfare, Cincinnati, Ohio.

meat into a water-soaked turkey roll casing, clamped at one end. After half of the meat was tightly packed, a thermocouple was inserted into the center of a large chunk of meat. Additional meat was packed around this chunk, and the remaining meat was added to fill the casing. The open end of the casing was drawn, tightened, and clamped. Another thermocouple without a needle was wrapped around the roll to check the water temperatures. Then the roll was immersed into a constant temperature water bath, and recordings were made. Turkey rolls were cooked at 54.4°C (130°F), 60°C (140°F), 62.8°C (145°F), 65.6°C (150°F), 71.1°C (160°F), 76.6°C (170°F), and 82.2°C (180°F) for four hours. Rolls were also cooked in water baths at 82.2°C (180°F) and 76.7°C (170°F) until an internal temperature of 65.6°C (150°F) or 71.1°C (160°F) was reached. At the termination of the cook, the roll was immediately immersed into a running water bath containing ice (approximately 10°C). Following cooling, the rolls were qualitatively and quantitatively evaluated for Salmonellae as previously described. The position of the thermocouple was also checked. S. senftenberg 775W was chosen for this study because of its reported heat resistance (Angelotti et al. 1961a)

#### Plant evaluations

The effectiveness of the turkey roll cooking procedures used in both plants was evaluated. While a roll was being formed, a thermocouple was inserted in the center of a large chunk of white meat located in the center portion of the roll. The lead was placed over the base end of the turkey roll shell. Seasoning and dark meat were added and a water-soaked casing was pulled over the meat and the roll shell. After this

operation, the casing was carefully clamped. Recordings were made during the normal cooking and cooling operations of the rolls located in the center, top, and bottom of the bath. Temperatures of cooking and cooling waters were evaluated at a distance approximately 1 inch from the rolls being investigated.



## RESULTS

Isolation of SalmonellaeIsolation of Salmonellae from farms and from trucks

Incidence of Salmonellae in feed samples      Feed samples were collected from 59 farms. These farms represented approximately half of the suppliers of turkeys to Plant B. Nine of these feed samples (9.3%) were positive for Salmonellae. In one sample two serotypes of Salmonellae were recovered. A listing of the serotypes isolated from feeds is shown in Table 16.

Only a few farms mixed their own feed. Nine samples of feed ingredients such as fish meal, meat meal, and bone meal were obtained from these farms. S. oranienburg was isolated from a meat and bone meal sample; however, no Salmonellae were recovered from the mixed feed at this farm.

The farmers from whom the feeds were obtained procured their feeds from 16 elevator sources. Feeds from six of these elevators were positive for Salmonellae on one or more occasions.

Incidence of Salmonellae in water troughs on farms      Of 29 samples of water collected on the range and in brooder houses from drinking troughs, 12 (41.4%) were positive for Salmonellae. Two serotypes were isolated from two of these samples. The trough water frequently contained the same serotypes that were recovered from the fecal droppings, as shown in Table 16.

Incidence of Salmonellae in turkeys and turkey droppings at farms  
Twenty turkeys that had recently died were autopsied, and Salmonellae

were found in ten of them (50%). Salmonellae were isolated from turkeys on six of 11 farms. Two serotypes were recovered from one turkey. The serotypes isolated were: S. worthington (5) S. anatum (3), S. bredeney (1), S. muenchen (1), and S. typhimurium var. copenhagen (1).

Thirty-four swabs were taken from fecal droppings. Although occasionally two swabs were taken from the same farm, any duplication represented poults in the brooder house and turkeys on the range or turkeys separated in different yards. Therefore, the swab samples represented separate lots entering the plant. Twenty-three of these samples were positive (67.7%). Serotypes isolated were: S. anatum (7), S. san diego (5), S. newington (2), S. bredeney (1), S. chester (1), S. halmstad (1), S. heidelberg (1), S. muenchen (1), S. senftenberg (1), S. typhimurium (1), and S. worthington (1).

#### Incidence of Salmonellae in fecal droppings from flocks entering plants

Composite samples of fecal droppings were obtained from truck beds. Turkey flocks arriving from 34 different farms were found to be positive for Salmonellae on 13 occasions (38.2%). As many as five serotypes were recovered from one flock. As in the case of droppings collected on the farms, loose stools were frequently observed.

#### Salmonellae isolated from "further processing" environments

Recoveries during each plant visit      Salmonellae were recovered during 19 of 20 visits (95%) to Plant A when freshly killed (and chilled overnight) turkeys were processed. The percentage of total positive samples ranged from 2.9-56.5% during individual visits and averaged 21.4%

for all visits. On most consecutive trips a different serotype predominated; however, usually more than one serotype was isolated. As many as eight serotypes were recovered on one visit. A total of 19 serotypes were found during these investigations.

The number of recoveries and the number of samples are indicated for chilled, eviscerated carcasses, meat at intermediate stages, finished product, contact environment, workers' hands and gloves, and the total samples are tabulated in Table 1. Percentages are entered in parenthesis for all of the category totals. The numbers shown in the Intermediate Stages column include turkey rolls which were subsequently cooked. The number of each Salmonella serotype isolated from swabs taken on each trip is also listed. Occasionally more than one serotype was recovered from a single sample; thus, the total of the Serotypes Isolated column sometimes exceeds the number indicated in the Total column.

During the processing of freshly killed turkeys, as indicated in Table 2, Salmonellae were isolated on 8 of 11 visits (72.7%) to Plant B. The total positive samples ranged from 16.7-68.7% and averaged 39.9%. As in Plant A, a different serotype usually predominated on a single visit; however, other serotypes were also found. A total of nine different serotypes was recovered. In addition to the isolations enumerated in Table 2, five recoveries were made from ten samples taken from trough gutters on different occasions.

Table 1. Salmonellae found during processing of freshly killed turkeys on each visit to Pl

Visit number	Chilled, eviscerated carcasses	Intermediate stages	Finished (uncooked) product	Contact environment	Workers' hands and gloves	Total
1	0/4	2/4	-*	1/5	-	3/13 (23.1%)
2	-	-	-	3/7	-	3/7 (42.9%)
3	3/5	-	3/5	7/13	-	13/23 (56.5%)
4	0/4	2/5	2/5	8/20	-	12/34 (35.3%)
5	0/6	0/1	2/10	7/18	-	9/35 (25.7%)
6	1/9	0/1	2/10	4/24	-	7/44 (15.9%)
7	0/12	1/4	1/6	8/25	5/7	15/54 (27.8%)
8	1/6	-	1/7	4/19	1/6	7/38 (18.4%)
9	1/5	-	1/14	2/24	0/5	4/48 (8.3%)
10	0/4	-	5/13	8/28	3/8	16/53 (30.2%)
11	-	0/1	3/18	5/25	3/5	11/49 (22.4%)
12	0/6	-	0/13	0/18	0/5	0/42 (0.0%)
13	0/10	1/1	2/13	4/15	1/5	8/44 (18.2%)
14	4/8	-	3/14	8/9	3/4	18/35 (51.4%)
15	0/6	0/3	2/8	1/23	1/5	4/45 (11.1%)
16	2/6	2/8	0/2	3/16	5/7	12/39 (30.8%)
17	-	-	0/2	3/14	-	3/16 (18.8%)
18	0/6	0/1	3/6	0/15	3/6	6/34 (17.6%)
19	0/4	-	0/4	1/14	0/5	1/27 (3.7%)
20	0/6	-	1/6	0/16	0/6	1/34 (2.9%)
Total	12/107 (11.2%)	8/29 (27.6%)	31/156 (19.9%)	77/348 (22.1%)	25/74 (29.6%)	153/714 (21.4%)

\* - No samples obtained. (Symbol used in Tables 2, 3, and 4.)

s on each visit to Plant A

Workers' hands and gloves			Total	Serotypes isolated
-	3/13	(23.1%)		<u>S. chester</u> 1, <u>S. typhimurium</u> 1, (Arizona 7:1,7,8(1))
-	3/7	(42.9%)		<u>S. chester</u> 3
-	13/23	(56.5%)		<u>S. anatum</u> 10, <u>S. typhimurium</u> 2, <u>S. tennessee</u> 1
-	12/34	(35.3%)		<u>S. cerro</u> 5, <u>S. anatum</u> 1, <u>S. bredeney</u> 1, <u>S. heidelberg</u> 1, <u>S. muenchen</u> 1, <u>S. newport</u> 1, <u>S. manhattan</u> 1, <u>S. schwarzengrund</u> 1
-	9/35	(25.7%)		<u>S. anatum</u> 7, <u>S. pullorum</u> 2
-	7/44	(15.9%)		<u>S. saint paul</u> , <u>S. newport</u> 1, <u>S. cerro</u> 1
5/7	15/54	(27.8%)		<u>S. san diego</u> 10, <u>S. saint paul</u> 2, <u>S. blockley</u> 1, <u>S. newport</u> 1, <u>S. schwarzengrund</u> 1
1/6	7/38	(18.4%)		<u>S. san diego</u> 6, <u>S. kentucky</u> 2
0/5	4/48	(8.3%)		<u>S. derby</u> 3, <u>S. san diego</u> 1
3/8	16/53	(30.2%)		<u>S. san diego</u> 11, <u>S. anatum</u> 6, <u>S. schwarzengrund</u> 1 <u>S. blockley</u> 1
3/5	11/49	(22.4%)		<u>S. typhimurium</u> 4, <u>S. reading</u> 4, <u>S. cerro</u> 2, <u>S. san diego</u> 1
0/5	0/42	(0.0%)		
1/5	8/44	(18.2%)		<u>S. blockley</u> 3, <u>S. anatum</u> 2, <u>S. cerro</u> 2, <u>S. saint paul</u> 1
3/4	18/35	(51.4%)		<u>S. blockley</u> 10, <u>S. anatum</u> 7, <u>S. cerro</u> 2, <u>S. saint paul</u> 2
1/5	4/45	(11.1%)		<u>S. saint paul</u> 2, <u>S. muenchen</u> 1, <u>S. muenster</u> 2
5/7	12/39	(30.8%)		<u>S. san diego</u> 7, <u>S. typhimurium</u> 6
-	3/16	(18.8%)		<u>S. cerro</u> 2, <u>S. blockley</u> 1
3/6	6/34	(17.6%)		<u>S. san diego</u> 3, <u>S. blockley</u> 2, <u>S. typhimurium</u> 1, <u>S. saint paul</u> 1
0/5	1/27	(3.7%)		<u>S. cerro</u> 1
0/6	1/34	(2.9%)		<u>S. typhimurium</u> 1
25/74	153/714			
29.6%)	(21.4%)			

Table 2. Salmonellae found during processing of freshly killed turkeys on each v

Visit number	Chilled, eviscerated carcasses	Intermediate stages	Finished product	Contact environment	Workers' hands and gloves	T
1	-	-	-	-	0/4	0/4
2	0/6	0/1	0/5	0/9	-	0/21
3	2/5	0/1	1/4	4/14	0/5	7/29
4	4/5	2/5	2/5	4/16	0/4	10/35
5	-	-	6/7	2/5	-	8/12
6	1/6	-	5/9	9/16	2/3	17/34
7	0/5	-	0/16	0/8	-	0/29
8	0/3	-	6/12	7/9	-	13/22
9	1/6	-	7/9	11/14	5/5	24/34
10	1/5	-	8/14	5/10	0/4	14/33
11	0/2	0/2	2/11	4/18	0/3	6/36
Total	9/43	2/9	37/92	44/119	7/29	99/301
	(20.9%)	(22.2%)	(40.2%)	(37%)	(25%)	(32.9%)

\*Salmonella serotypes also isolated from trough gutters.

on each visit to Plant B

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Total	Serotypes isolated
<hr/>	
0/4 (0.0%)	
0/21 (0.0%)	
7/29 (24.1%)	<u>S. give</u> 7,*
10/35 (28.0%)	<u>S. saint paul</u> 9, <u>S. anatum</u> 1,*
8/12 (66.7%)	<u>S. san diego</u> 8
17/34 (53.0%)	<u>S. montevideo</u> 17, <u>S. anatum</u> 2,*
0/29 (0.0%)	
13/22 (59.1%)	<u>S. san diego</u> 11, <u>S. newport</u> 2, <u>S. muenchen</u> 1, <u>S. saint paul</u> 1, <u>S. typhimurium</u> 1
24/34 (68.7%)	<u>S. anatum</u> 18, <u>S. san diego</u> 4, <u>S. newport</u> 3,*
14/33 (42.4%)	<u>S. cerro</u> 13, <u>S. anatum</u> 1,*
6/36 (16.7%)	<u>S. san diego</u> 3, <u>S. anatum</u> 2, <u>S. cerro</u> 1
99/301	
(32.9%)	

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When Plant A processed thawed turkey carcasses which had been frozen for varying lengths of time (usually more than three months), results similar to those found during the processing of freshly killed carcasses were observed. Recoveries of Salmonellae were made during five of seven visits (71.4%). The percentage of total positive samples ranged from 17.9-54.5% and averaged 20.5%. Although S. san diego was found more frequently and on more occasions than any other serotype, it was not isolated on two of the visits. A total of eight serotypes was found. The recoveries and percentages - as well as a listing of the serotypes isolated - are shown in Table 3.

When Plant B processed thawed turkey carcasses, Salmonellae were isolated during five of ten visits. In addition to these isolations, S. schwarzengrund was also recovered from a floor drain. Recoveries of Salmonellae were made in only 9.1% of the samples. Six different serotypes were found. Results are indicated in Table 4.

Thus, Salmonellae were isolated on 87.1% of the visits when the plants were engaged in "further processing" freshly killed turkeys and on 58.8% of the visits when the plants were engaged in processing thawed turkeys. Salmonellae were recovered on 77.1% of all visits to both plants. Twenty-three different serotypes were isolated from turkey meat or from the "further processing" environment.

Incidence of Salmonellae on surfaces of turkey meat before and after "further processing" In Plant A, 11.2% of the chilled, eviscerated carcasses were positive for Salmonellae. Data for chilled carcasses, partially processed meat, rolls which were subsequently cooked, and the



Table 3. Salmonellae found during processing of thawed turkeys on each visit to Plant A

Visit number	Thawed, eviscerated carcasses	Intermediate stages	Finished product	Contact equipment	Total		
1	-	1/6	-	6/8	7/14	(50.0%)	<u>S.</u> t
2	0/10	0/2	0/10	0/18	0/40	(0.0%)	<u>S.</u> s
3	0/6	1/1	3/7	1/14	5/28	(17.9%)	<u>S.</u> s
4	0/8	0/1	0/7	0/10	0/26	(0.0%)	<u>S.</u> s
5	0/6	0/2	3/7	5/17	8/32	(25.0%)	<u>S.</u> s
6	3/6	-	3/6	7/10	13/22	(54.5%)	<u>S.</u> s
7	0/6	-	2/9	3/8	5/23	(21.7%)	<u>S.</u> c
Total	3/42 (7.1%)	2/12 (16.7%)	11/43 (25.5%)	22/85 (25.9%)	38/185 (20.5%)		

Table 4. Salmonellae found during processing of thawed turkeys on each visit to Plant B

Visit number	Thawed, eviscerated carcasses	Intermediate stages	Finished product	Contact equipment	Total		
1	0/5	1/3	-	0/12	1/20	(5.0%)	<u>S.</u> s
2	0/3	0/5	-	0/12	0/20	(0.0%)	<u>S.</u> s
3	0/3	0/2	-	0/6	0/11	(0.0%)	<u>S.</u> s
4	0/2	2/10	-	2/10	4/22	(9.1%)	<u>S.</u> s
5	-	-	3/3	2/7	5/10	(50.0%)	<u>S.</u> s
6	-	0/3	-	0/2	0/5	(0.0%)	<u>S.</u> s
7	0/3	0/4	0/3	0/10	0/21	(0.0%)	<u>S.</u> s
8	-	0/2	-	1/5	1/7	(14.3%)	<u>S.</u> t
9	-	0/3	-	0/3	0/6	(0.0%)	<u>S.</u> t
10	-	-	1/6	0/5	1/11	(9.1%)	<u>S.</u> a
Total	0/16 (0%)	3/32 (9.4%)	4/12 (33.3%)	5/72 (6.9%)	12/130 (9.2%)		

\*S. schwarzengrund isolated from a drain.

to Plant A

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1 Serotypes isolated

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50.0%) S. tennessee 7  
(0.0%)  
17.9%) S. san diego 5  
(0.0%)  
25.0%) S. san diego 4, S. muenster 3, S. reading 2, S. infantis 1  
54.5%) S. san diego 6, S. binza 4, S. chester 3  
21.7%) S. cerro 5

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to Plant B

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. Serotypes isolated

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5.0%) S. schwarzengrund 1  
0.0%)  
0.0%)  
9.1%) S. san diego 3, S. cerro 1  
0.0%) S. schwarzengrund 3, S. saint paul 2  
0.0%)  
0.0%)  
4.3%) S. typhimurium 1  
0.0%)  
9.1%) S. anatum 1

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finished product are given in Table 5. Since the uncooked rolls and finished products were similarly prepared, and the rolls gave an indication of the contamination load of a product which was not heat processed, the results have been combined. For this combined total, 20.5% of the samples were positive for Salmonellae. In Plant B, chilled, eviscerated carcasses yielded Salmonellae in 20.9% of the samples, and the finished product and rolls were positive in 39.4% of the samples (Table 5).

When thawed turkeys were processed in Plant A, thawed, eviscerated carcasses were positive for Salmonellae in 7.1% of the samples, and the finished products were positive in 23.9% of the samples. In Plant B, Salmonellae were not isolated from 16 samples of thawed, eviscerated carcasses; these organisms were isolated from 25% of the samples of rolls and other finished products. Results for both plants are tabulated in Table 6. A higher percentage of recoveries of Salmonellae was always observed in the finished product as compared to carcasses prior to boning operations.

Incidence of Salmonellae on contact surfaces of equipment In Plant A, 22.1% of 348 samples of contact equipment taken at the time of processing freshly killed turkeys yielded Salmonellae. The items with a higher percentage than the average were the line tables, saws, work tables, conveyors, and pans. In fact, most of the items were contaminated to some extent. Data from Plant B illustrated this same point. Of 119 samples of contact equipment, 37% were positive for Salmonellae. Items with a higher percentage than the average were the tie forms, automatic tying machines, line tables, saws, cutting boards,

Table 5. Salmonellae on surfaces of turkey meat before and after "further processing"

Product	Number of samples	Number positive	Percent positive
Plant A			
Chilled, eviscerated carcasses	107	12	11.2
Partially processed meat	14	4	28.6
Rolls to be subsequently cooked	15 } 171	4 } 35	26.7 } 20.5
Finished products (uncooked)	156	31	19.9
Plant B			
Chilled, eviscerated carcasses	43	9	20.9
Partially processed meat	2	0	0
Rolls to be subsequently cooked	7 } 99	2 } 39	28.6 } 39.4
Finished products (uncooked)	92	37	40.2

Table 6. Salmonellae on surfaces of previously frozen turkey meat before and after "further processing"

Product	Number of samples	Number positive	Percent positive
Plant A			
Thawed, eviscerated carcasses	42	3	7.1
Partially processed meat	12	2	16.7
Finished product	46	11	23.9
Plant B			
Thawed, eviscerated carcasses	16	0	0
Partially processed meat	21	2	9.5
Rolls to be cooked	8 } 20	1 } 5	12.5 } 25
Finished product (uncooked)	12	4	33.3

pans and scales. As in Plant A, most items were contaminated to some extent. The number of samples collected from each item varied due to the daily plant operations; for example, in Plant B the saw was used only during two sample trips, and so only two samples were obtained. Results are tabulated in Table 7.

Results are tabulated in Table 8 for the incidence of Salmonellae on contact surfaces of equipment during the time thawed, eviscerated turkeys were processed. In Plant A, 25.9% of 85 samples were positive for Salmonellae. A high percentage of recoveries were found in samples of the baggers, saws, conveyors, meat tanks, scales, pincers, tables, sharpeners, and the line table. In Plant B, only 6.9% of 72 samples were positive for Salmonellae during the processing of thawed, eviscerated turkeys. Recoveries were made from a grinder, line table, work table, and pan.

Salmonellae present on workers' hands and gloves during processing operations The hands of 70 workers were sampled, and Salmonellae were isolated from 21 (30.0%). Rubber gloves were positive 37.5% of the time, and wire mesh safety gloves were positive 31.2% of the time. Similar data were observed from samples taken from both plants, and these results are shown in Table 9. Usually, the same serotypes were recovered from the workers' hands and from gloves that were found throughout the plant on any one sampling trip. Although staphylococci were not routinely evaluated, coagulase positive staphylococcal strains were isolated from the hands of three workers prior to commencing work.

Table 7. Salmonellae on contact surfaces of "further processing" equipment when processing freshly killed turkeys

Equipment	Number of samples	Number positive	Percent positive
Plant A			
Line table	22	12	54.5
Saws	10	3	30.0
Work tables	55	16	29.1
Conveyors	28	8	28.6
Pans	66	16	24.2
Sharpeners	14	3	21.4
Knives	25	5	20.0
Cutting boards	27	5	18.5
Scales	19	3	15.8
Chill tanks	19	3	15.8
Tie forms	8	1	12.5
Meat tanks	11	1	9.1
Pincers	9	0	0.0
Automatic tying machines	17	0	0.0
Roll shells	7	0	0.0
Baggers	8	0	0.0
Automatic injectors	3	0	0.0
Total	348	77	22.1
Plant B			
Tie forms	3	3	100.0
Automatic tying machine	4	3	75.0
Line table	9	5	55.5
Saws	2	1	50.0
Cutting boards	11	5	45.5
Pans	11	5	45.5
Scales	22	9	40.9
Work tables	12	4	33.3
Conveyors	10	3	30.0
Knives	11	3	27.3
Baggers	8	2	25.0
Chill tanks	8	1	12.5
Sharpeners	5	0	0.0
Roll shells	2	0	0.0
Scoop	1	0	0.0
Total	119	44	37.0

Table 8. Salmonellae on contact surfaces of "further processing" equipment when processing thawed turkeys

Equipment	Number of samples	Number positive	Percent positive
Plant A			
Bagger	1	1	100.0
Saws	2	2	100.0
Conveyors	4	3	75.0
Meat tanks	2	1	50.0
Scales	5	2	40.0
Pincers	3	1	33.3
Work tables	9	3	33.3
Sharpeners	6	2	33.3
Line table	6	2	33.3
Pans	13	3	23.1
Cutting boards	6	1	16.7
Knives	7	1	14.3
Automatic tying machines	6	0	0.0
Chill tanks	14	0	0.0
Tie form	1	0	0.0
Total	85	22	25.9
Plant B			
Grinder	1	1	100.0
Line table	9	2	25.0
Work tables	4	1	25.0
Pans	13	1	7.7
Conveyors	4	0	0.0
Scales	10	0	0.0
Cutting boards	7	0	0.0
Knives	6	0	0.0
Chill tanks	4	0	0.0
Meat tank	1	0	0.0
Packaging areas	4	0	0.0
Roll shells	4	0	0.0
Saws	3	0	0.0
Pick	1	0	0.0
Shovel	1	0	0.0
Automatic tying machine	1	0	0.0
Total	72	5	6.9

Table 9. Salmonellae present on workers' hands and gloves during processing operations

	Number examined	Number positive	Percent positive
Hands			
Plant A	44	15	34.1
Plant B	26	6	23.0
Total	70	21	30.0
Rubber gloves			
Plant A	14	5	35.7
Plant B	2	1	50.0
Total	16	6	37.5
Wire gloves			
Plant A	16	5	31.2

Salmonellae isolated from turkey carcasses and from equipment in the picking and eviscerating environment

In Plant B, after turkeys were killed and scalded, carcasses passed through picking machines, tumbled down a chute, slid across a table, and were rehung. Following this last step, carcasses were sampled and 63% of the samples revealed Salmonellae. After spray washing, Salmonellae were recovered from 18.2% of the samples. Findings were further reduced to 10% following evisceration, washing, and spin chilling. Carcasses after chilling overnight and just prior to packaging as whole turkeys were found to contain Salmonellae on 10 of 58 samples (17.3%). These results are shown in Table 10 and graphically illustrated in Figure 1.



Table 10. Salmonellae on turkey carcasses at various stages of processing

Stage of processing	Plant A		Plant B	
	Number of samples	Number positive	Number of samples	Number positive
After picking	10	2	46	29 (63.0%)
After washing	10	1	33	6 (18.2%)
Before icing	10	0	50	5 (10.0%)
After chilling	16	0	58	10 (17.3%)
"Further processed" products	16	4	*	

\*No samples obtained from "further processed" items at Plant B.

In Figure 1 the line indicating the percentages of Salmonellae on carcasses is not continuous. A break was made to indicate that the study of the "further processed" products was conducted at a different time and on different flocks than the picking and eviscerating study.

Two flocks were followed through the processing operations in Plant A. Two of ten samples obtained from carcasses after picking were positive for Salmonellae. Of samples taken after carcasses were spray washed, 10% contained Salmonellae. These organisms were not isolated from carcasses before icing or after 24 hours of chilling. Of 16 samples of the "further processed" products, four (25%) were positive for Salmonellae (Table 10).

In Plant A, 72.2% of the samples of equipment in the picking environment were positive, whereas 33% of the samples of eviscerating equipment were positive. During the sampling trips that the flocks were followed through the plant only one item of "further processing" equipment was found to be contaminated with Salmonellae (Table 11).

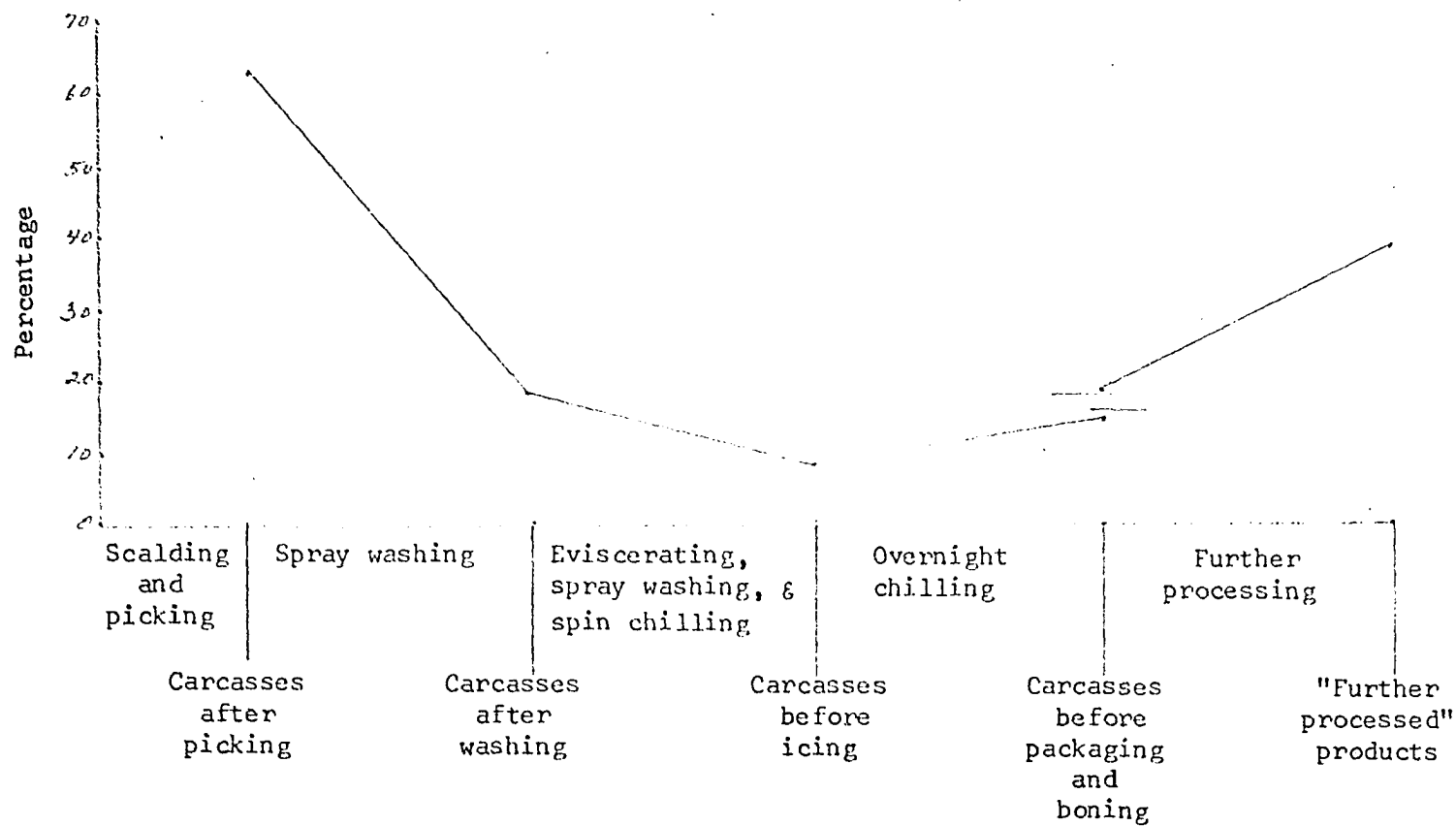


Figure 1. Percentage of Salmonellae isolations at successive stages of processing turkeys in Plant B

Table 11. Salmonellae isolated during the processing of two turkey flocks in Plant A

Item	Number sampled	Number positive
Picking Environment		
Neck picker	2	2
Picker 1	2	1
Picker 2	2	2
Wing picker	2	1
Picker 3	2	2
Picker 4	2	2
Hock picker	2	1
Washer cover	2	0
Feet remover	2	2
Evisceration Environment		
Gutter	2	1
Head remover	2	1
Metal shield	1	0
Neck remover	2	0
Grading table	2	1
Boning Environment*		
Total	27	16 (59.3%)

\*One of 45 contact surfaces positive for Salmonellae (previously reported).

In regard to equipment in Plant B, Salmonellae were isolated from 75.6% (62 of 82) of the samples taken from the picking environment. In the eviscerating environment, 28.9% (44 of 152) of the equipment was contaminated with Salmonellae. Of samples taken from the packaging area, 16% were positive for Salmonellae. An itemization of individual items of equipment is shown in Table 12.

Table 12. Salmonellae on picking and eviscerating equipment in Plant B

Item	Number sampled	Number positive	Percent
Picker 1	14	12	85.7
Spiral, automatic picker	14	12	85.7
Transfer table (picking room)	13	11	84.6
Picker 2	14	11	78.6
Chute (picking room)	13	9	69.2
Trussing table	16	10	62.5
Evisceration gutter	14	8	57.1
Metal shield, washer	7	4	57.1
Picker 3	14	7	50.0
Washer, after evisceration	5	2	40.0
Packaging table	9	3	33.3
Slide, chiller 1 to chiller 2	13	4	30.8
Head remover	13	4	30.8
Spin chiller 1	14	4	28.6
Chill chute and grading table	14	4	28.6
Evisceration knives	12	2	16.7
Bagger	8	1	12.5
Spin chiller 2	14	1	7.1
Spin chiller 3	14	1	7.1
Chill tanks	10	0	0.0
Other equipment	6	0	0.0
Scales	8	0	0.0
Total	259	110	42.5

Salmonellae isolated from equipment after clean-up operations

In Plant A, three of 19 samples (15.8%) of picking equipment that had been cleaned were found to contain Salmonellae. However, Salmonellae were neither isolated from two samples of eviscerating equipment nor from 15 samples of "further processing" equipment. Thus, 8.3% of samples taken from equipment after cleaning contained Salmonellae.

In Plant B, two Salmonellae were isolated from 12 samples of the

picking equipment after clean-up operations. Salmonellae were not isolated either from 18 samples taken from eviscerating and packaging equipment or from two samples taken from boning equipment. Thus, 6.2% of the samples taken from equipment after cleaning revealed Salmonellae. All recoveries were made only from defeathering equipment.

#### Tracing Salmonellae from the farm through the processing plant

Visits were made to several farms supplying turkeys to Plant B, where samples of feed, fecal droppings, and trough water were obtained. Flocks arriving at the plant during the first and third weeks of operation were evaluated. The results of this study are tabulated in Table 13.

During the first day's operation (I), three flocks entered the plant. No Salmonellae were isolated from Farm A or from fecal droppings collected from the truck delivering Flock A to the plant. However, four serotypes were isolated following the processing of this flock. Then Flock B, in which S. typhimurium had been isolated from fecal droppings on the farm, entered the plant. S. typhimurium and some of the previously isolated types were recovered from turkey meat and equipment following the processing of this flock. Near the end of the day's operation, a few hundred breeder turkeys (Flock C) were processed in the plant. S. san diego had previously been isolated from fecal droppings and trough water at the farm; however, in most all the samples from equipment and turkey meat, S. cerro was isolated. Several samples also contained serotypes that had been isolated earlier in the day. The next day (II) Flock D, in which S. san diego had been isolated, entered the plant. S. san diego

Table 13. Salmonella serotypes isolated from turkey carcasses and from equipment during pro

Day	I			II	III			IV	**	V
Flock	A	B	C	D	E	F	(EF)	†		G
Fecal droppings, farm	-	e	g	g	i,j	b				k
Water troughs, farm	-	-	g	g	i	-				k
Fecal droppings, truck	-	-	-	g	-	-				b
Picker 1	a	-	a	a,g			c,i	g		m
Picker 2	-	e	a,e				b,c	-		m
Picker 3	-	-	e	e			g	-		m
Spiral picker	b,c	a,c	b,d	d,f			a,b,d	b		-
Chute	-	a,e	b,d	g			c	-		-
Table (picking)	-	b,e	f	g			b	-		-
Carcasses after picking			b,e,f	g	a,b,c,h	b,g				l,i
Carcasses after washing					-	-				-
Gutter	-	-	f				b	-		l,i
Knives	-	-	f				-			l
Head remover			f	b,g			-	-		-
Trussing table	b,d	e	f	g			e,i	-		-
Spin chill 1	-	-	b	g			-	-		-
Slide	a	-	f	f			-	-		-
Spin chill 2	-	-	-	-			-	-		-
Spin chill 3	-	-	-	-			-	-		-
Chute and grade table	-	-	f	g			e	-		-
Carcasses before icing	-	-	f	g	a	-				-
Chill tank*		-		-	-	-		-		-
Carcasses before packaging*	c	e	f	g	i	f,i				-
Grade and packaging table*		-		-			i			-
Scales*				-			-			-
Baggers*				-			-			-

<sup>1</sup>Key: a, S. infantis; b, S. anatum; c, S. chester; d, S. bredeney; e, S. typhimurium; f, S. senftenberg; k, S. halmstad; l, S. muenchen; m, S. stanley; n, S. saint paul; o, S. blo  
 -, negative for Salmonellae; all blank spaces indicate that no samples were taken.

†After clean up.

\*Isolations made on the following day.

\*\*Lapse of one week.

carcasses and from equipment during progressive stages of processing 15 consecutive flocks<sup>1</sup>

	III			IV	**	V	VI				VII			VIII	IX	X	
	E	F	(EF)	†		G	H	I	(HI)	J	K	L	(KL)	M	N	†	O
	i,j	b				k	-	b			b	-		-	-		b
	i	-				k	-	-			-	-		-	-		b
	-	-				b	l,n	-		-	-	-		-	-		b
g			c,i	g		m			i	m			m,p	b,p	p	-	-
			b,c	-		m			-	m			b,g	b	p	-	-
			g	-		m			-	-			-	-	-	-	-
f			a,b,d	b		-			l	-			g	g	a	-	b
			c	-		-			-	-			g	c	q	-	b
			b	-		-			l	b			g	g	c	-	b
	a,b,c,h	b,g				l,m	n,o	g		d,g	b	g		c	a		b
	-	-				-	g,l	-		-	e	g		-			b
			b	-		l,m			b	b			-	g	c	-	-
			-	-		l			-	-			-	-	-	-	-
g			-	-		-	n		-	c			-	-	-	-	-
			e,i	-		-	o		-	b			-	g	-	-	-
			-	-		-			b	-			-	-	-	-	-
			-	-		-			-	-			-	g	-	-	-
			-	-		-			-	-			-	g	-	-	-
			-	-		-			-	-			-	p	-	-	-
			e	-		-			-	-			-	-	-	-	-
	a	-				-			-	-	-	-		-	-		-
	-	-		-		-	-	-		-	-	-		-	-		-
	i	f,i				-	-	-		-	-	-		-	-	-	-
			i			-			b	-			-	-	-		-
			-			-			-	-			-	-	-		-
			-			-			b	-			-	-	-		-

er; d, S. bredeney; e, S. typhimurium; f, S. cerro; g, S. san diego; h, S. derby; i, S. newington  
S. stanley; n, S. saint paul; o, S. blockley; p, S. schwarzengrund; q, S. montevideo;  
e that no samples were taken.

was isolated from fecal droppings on the truck as well as from a great deal of processing equipment and from turkey meat samples. S. cerro, the organism that was so readily isolated at the end of the previous day, was recovered from the spiral picker and the slide between two spin chillers; however, it was not isolated from the plant during any future sampling visit. The following day (III) two flocks (E and F) entered the plant. Unfortunately, there was no opportunity to sample between each flock since delivery trucks from each farm arrived at the plant in an alternate fashion. At Farm E, S. newington and S. senftenberg had been previously isolated, and at Farm F, S. anatum had been previously recovered. S. anatum and S. newington were isolated during both surveys. Several serotypes previously isolated and S. derby were also recovered. The next day (IV) no turkeys were killed and equipment which had been cleaned was evaluated. S. san diego and S. anatum were isolated from two picking machines.

A week lapsed during which time plant evaluations were not made. Five flocks were processed during this period of time. The following week the surveys were continued. At Farm G, S. halmstad was isolated from fecal droppings and trough water. Fecal droppings from the turkeys entering the plant revealed S. anatum (day V). However, plant isolations revealed S. muenchen and S. stanley. The next day (VI), S. muenchen and S. saint paul were recovered from fecal droppings from Flock H. These serotypes, as well as S. san diego and S. blockley were isolated from turkey meat and equipment. Next, Flock I, in which S. anatum had been identified, arrived at the plant. S. san diego was recovered from a turkey meat sample. Following the processing of these



two flocks, S. anatum, S. muenchen, and S. newington were isolated when equipment was swabbed. Later, Flock J entered the plant and various serotypes were recovered. The following day (VII), Flock K, in which S. anatum had been isolated from fecal droppings on the farm, entered the plant. S. anatum and S. typhimurium were recovered from turkey meat. Later, Flock L entered the plant and S. san diego was isolated from turkey meat. After these flocks were processed, the equipment was evaluated and S. anatum, S. san diego, and S. schwarzengrund were recovered. Later in the day Flock M entered the plant, and the aforementioned serotypes, as well as S. chester, were found. The next day (VIII), Flock N entered the plant and S. schwarzengrund, S. infantis, S. chester, and S. montevideo were isolated. The following day (IX) no turkeys entered the plant, and Salmonellae were not isolated from the equipment after cleaning. On the first day of the next week (X), Flock O, in which S. anatum had been previously recovered from fecal droppings and the water trough on the farm, entered the plant. S. anatum was isolated from the fecal droppings on the truck, on turkey meat, and on picking equipment.

Following the observation of 52% positive cultures and five serotypes from "further processing" environment, an attempt was made to check on the background of the incriminated turkey flock. On a return visit to the plant the situation was discussed with plant officials. From the plant inspector's records, it was observed that many turkeys from the flock in question were condemned because of air sac infection and septicemia. Breast portions were removed from many of the turkeys that were kept for processing. On the day of this inquiry, more turkeys from the same farm

were processed. As with the first lot, several turkeys were condemned. Swabs were taken of the "further processing" environment, and 68.7% of the cultures revealed Salmonellae. Six serotypes were identified.

A local practicing veterinarian was contacted. He had recently treated the flock and reported that Mycoplasma were isolated from several birds. Next, the farm was visited. This was a large farm that processed its own feed. The turkeys that were surveyed had been kept on ranges in separate areas. Feed from field feeders and meat scrap and bone meal were sampled. Turkey manure on the feeder lids and range sheds were also cultured. All of these samples were negative for Salmonellae. Previously, feed and meal samples were obtained from this farm, and S. oranienburg was isolated from a meat scrap and bone meal sample; however, this serotype was not isolated during the current investigation.

#### Serotypes isolated

Five hundred forty-nine isolations of Salmonellae were made from the two processing plants studied (243 from Plant A and 306 from Plant B). Twenty-five serotypes were represented in these recoveries. Twenty-two serotypes were isolated from Plant A and 17 from Plant B. S. san diego was the type most frequently isolated from both plants (24.8% of the recoveries from Plant A and 21.6% of the recoveries from Plant B). S. anatum was also frequently isolated from both plants. Other serotypes that were frequently identified from both plants included S. cerro, S. typhimurium, S. saint paul, and S. chester. Some types, such as S. blockley, were isolated a number of times from Plant A, but infrequently from Plant B; conversely, S. montevideo was recovered from Plant B but not from Plant A (Table 14).

Table 14. Salmonella serotypes isolated from turkey products and the environment of Plant A and Plant B

Serotype	Plant A		Plant B		Total	
	Number isolated	Per- cent	Number isolated	Per- cent	Number isolated	Per- cent
<u>S. san diego</u>	60	24.8	66	21.6	126	23.0
<u>S. anatum</u>	40	16.5	63	20.6	103	18.8
<u>S. cerro</u>	21	8.6	33	10.8	54	9.8
<u>S. typhimurium</u>	27*	11.1	18	5.9	45	8.2
<u>S. saint paul</u>	14	5.8	18	5.9	32	5.8
<u>S. blockley</u>	26	10.7	1	0.3	27	4.9
<u>S. chester</u>	12	4.9	15	4.9	27	4.9
<u>S. montevideo</u>	0	0.0	18	5.9	18	3.3
<u>S. infantis</u>	1	0.4	15	4.9	16	2.9
<u>S. muenchen</u>	2	0.8	11	3.6	13	2.4
<u>S. schwarzengrund</u>	3	1.2	10	3.3	13	2.4
<u>S. newington</u>	1	0.4	9	2.9	10	1.8
<u>S. bredeney</u>	1	0.4	7	2.3	8	1.5
<u>S. newport</u>	3	1.2	5	1.6	8	1.5
<u>S. give</u>	0	0.0	8	2.6	8	1.5
<u>S. stanley</u>	0	0.0	8	2.6	8	1.5
<u>S. tennessee</u>	8	3.3	0	0.0	8	1.5
<u>S. reading</u>	6	2.5	0	0.0	6	1.1
<u>S. muenster</u>	5	2.1	0	0.0	5	0.9
<u>S. derby</u>	3	1.2	1	0.3	4	0.7
<u>S. binza</u>	4	1.7	0	0.0	4	0.7
<u>S. kentucky</u>	2	0.8	0	0.0	2	0.4
<u>S. pullorum</u>	2	0.8	0	0.0	2	0.4
<u>S. heidelberg</u>	1	0.4	0	0.0	1	0.2
<u>S. manhattan</u>	1	0.4	0	0.0	1	0.2
Total	243**		306		549	

\*Four S. typhimurium variety copenhagen included in this figure.

\*\*Two Arizona 7:1,7,8 also isolated.

Table 15 shows that S. anatum was found on 25 of 67 plant visits (37.3%), ranking as the second most common in total isolations. S. san diego was isolated on 20% of the visits. For the most part, the types most frequently recovered (Table 14) were also found on more occasions (Table 15). A few exceptions included S. montevideo, S. give, and S. tennessee. Several isolations of these organisms were made, but all of these isolations were made on one or two occasions.

Table 16 summarizes information regarding the total isolations of each serotype and classifies these findings according to the sources from which they were obtained.

#### Isolations and Enumerations of Indicator Bacteria

In Plant A, a median of 47,000 aerobic organisms per gram was determined for the chilled, dressed carcasses, and a median of 75,000 was determined for the finished products; whereas in Plant B, a median of 17,000 aerobic organisms per gram was observed for the chilled, dressed carcasses, and a median of 11,000 was observed for the finished products.

In Plant A, a median of 12 coliforms per gram was determined for the chilled, dressed carcasses, and a median of 26 was determined for the finished products. In Plant B, a median of 10 coliforms per gram was found for the chilled, dressed carcasses, and a median of 30 was found for the finished products.

A median of 27 enterococci per gram was recorded for the chilled, eviscerated carcasses, and a median of 41 was recorded for the finished products in Plant A. In Plant B, a median of 12 enterococci per gram

Table 15. Occasions in which Salmonella serotypes were found in processing plants (67 visits)

Serotype	Number of times isolated	Percent
<u>S. anatum</u>	25	37.3
<u>S. san diego</u>	20	30.0
<u>S. typhimurium</u>	16	23.9
<u>S. cerro</u>	11	16.4
<u>S. saint paul</u>	11	16.4
<u>S. chester</u>	10	14.9
<u>S. blockley</u>	8	11.9
<u>S. schwarzengrund</u>	8	11.9
<u>S. infantis</u>	7	10.4
<u>S. muenchen</u>	6	9.0
<u>S. bredeney</u>	5	7.5
<u>S. newington</u>	5	7.5
<u>S. newport</u>	5	7.5
<u>S. derby</u>	2	3.0
<u>S. montevideo</u>	2	3.0
<u>S. reading</u>	2	3.0
<u>S. stanley</u>	2	3.0
<u>S. tennessee</u>	2	3.0
<u>S. give</u>	1	1.5
<u>S. heidelberg</u>	1	1.5
<u>S. kentucky</u>	1	1.5
<u>S. manhattan</u>	1	1.5
<u>S. muenster</u>	1	1.5
<u>S. pullorum</u>	1	1.5
<u>S. binza</u>	1	1.5

Table 16. Sources of Salmonella serotypes isolated

Serotype	Feed or feed ingredient	Trough water	Turkeys or turkey feces	Turkey meat*	Contact environment	Work and
<u>S. anatum</u>	3	5	14	18	58	
<u>S. binza</u>		1			4	
<u>S. blockley</u>				8	15	
<u>S. bredeney</u>	1	1	3	1	7	
<u>S. cerro</u>	2			7	32	
<u>S. chester</u>	1	1	2	4	20	
<u>S. derby</u>				1	2	
<u>S. give</u>				2	4	
<u>S. halmstad</u>		1	1			
<u>S. heidelberg</u>		1	1		1	
<u>S. infantis</u>				3	13	
<u>S. kentucky</u>				1		
<u>S. manchester</u>			1			
<u>S. manhattan</u>				1		
<u>S. montevideo</u>	1		1	1	9	
<u>S. muenchen</u>	1	1	4	4	5	
<u>S. muenster</u>					2	
<u>S. newington</u>		1	2		6	
<u>S. newport</u>			1		3	
<u>S. oranienburg</u>	1					
<u>S. pullorum</u>					2	
<u>S. reading</u>					4	
<u>S. saint paul</u>			3	9	12	
<u>S. san diego</u>		2	8	23	58	
<u>S. schwarzengrund</u>				1	6	
<u>S. senftenberg</u>	1		1			
<u>S. stanley</u>				1	6	
<u>S. tennessee</u>				1	7	
<u>S. typhimurium</u>			3	10	25	
<u>S. worthington</u>			6			
rough: d,1,2			1			
Arizona 7:1,8,7				2		
Total	11	14	52	98	301	

\*Includes rolls to be cooked.

Contact environment	Workers' hands and gloves	Finished product	Non-contact environment	Total
58	6	17	4	125 (19.8%)
4				5 (0.8%)
15	4			27 (4.3%)
7				13 (2.1%)
32		14	1	56 (8.9%)
20	1	1	1	31 (4.9%)
2	1			4 (0.6%)
4		1	1	8 (1.3%)
				2 (0.3%)
1				3 (0.5%)
13				16 (2.5%)
	1			2 (0.3%)
				1 (0.2%)
				1 (0.2%)
9	2	5	1	20 (3.2%)
5	1	2	1	19 (3.0%)
2		3		5 (0.8%)
6		4		13 (2.1%)
3	2	3		9 (1.4%)
				1 (0.2%)
2				2 (0.3%)
4	1	1		6 (1.0%)
12	2	6	3	35 (5.6%)
58	13	33	1	138 (21.9%)
6	1	4	1	13 (2.1%)
				2 (0.3%)
6			1	8 (1.3%)
7				8 (1.3%)
25	5	4	1	48 (7.6%)
				6 (1.0%)
				1 (0.2%)
				2 (0.3%)
301	40	98	16	630

was noted for chilled, eviscerated carcasses, and a median of 18 was noted for the finished product.

The highest and lowest numbers and an itemization of the findings on individual finished products, as well as the median for total aerobes, coliforms, and enterococci, are indicated in Table 17. With all three groupings a wide range of counts were found, with some extremely high or low counts; thus no attempt was made to determine the means. No correlation was observed between these counts and the presence or absence of Salmonellae.

Coagulase-positive staphylococci were also isolated from chilled, eviscerated carcasses and from finished products, although no attempt was made to quantitate these results.

#### The Thermal Processing of Turkey Rolls

##### Laboratory study

After the inoculation of over one million S. senftenberg 775W cells in turkey rolls, this serotype was recovered from the rolls cooked for four hours in water baths at temperatures of 54.4°C (130°F) and 60°C (140°F), but this organism was not recovered when the rolls were cooked for the same period of time at 62.8°C (145°F), 65.6°C (150°F), 71.1°C (160°F), 76.6°C (170°F), and 82.2°C (180°F). The white meat had a distinct pink color at temperatures below 71.1°C (160°F). Counts are tabulated in Table 18, and heating and cooling curves are illustrated in Figure 2.



Table 17. Aerobic organisms, coliforms, and enterococci per cm<sup>2</sup> on the surface of turkey meat b finished products before freezing

	Number of samples	Total aerobes			Range		Co.	
		Range (x 10 <sup>3</sup> )		Median (x 10 <sup>3</sup> )				
Plant A								
Chilled, eviscerated carcasses	56	0.55	-	890	47	< 0.5	-	2
Finished product	119	5.1	-	860	75	0.5	-	19
Rolls, uncooked	32	5.1	-	860	57	0.5	-	1
Roasts	30	8.3	-	160	62	6.5	-	3
Pineapple dip roasts	23	9.5	-	230	43	0.5	-	2
Breast filet	6	12	-	800	100	11	-	6
Leg segment	7	29	-	220	66	1.5	-	
Thigh segment	12	160	-	570	230	25	-	19
Breast segment	9	40	-	470	300	11	-	3
Plant B								
Chilled, eviscerated carcasses	40	0.40	-	11,000	17	< 0.5	-	130,00
Finished product	82	0.75	-	58,000	11	< 0.5	-	7,40
Rolls, uncooked	8	2.4	-	75	7	8	-	11
Roasts	22	1.7	-	58,000	29	11	-	7,40
Breast segment	19	0.75	-	160	5	< 0.5	-	80
Leg segment	16	1.2	-	3,300	14	0.5	-	3,30
Thigh segment	7	2	-	12	3.2	0.5	-	1
Wing segment	5	4	-	110	8.5	7.5	-	20
Logs	5	3.6	-	46	12	1.5	-	2

he surface of turkey meat before "further processing" operations and on the

(x 10 <sup>3</sup> )	Coliform				Enterococci			
	Range		Median		Range		Median	
7	< 0.5	-	230	12	< 0.5	-	730	27
5	0.5	-	1900	26	1	-	670	41
7	0.5	-	140	26	19	-	670	68
2	6.5	-	310	34	2.5	-	340	64
3	0.5	-	200	12	1	-	270	11
)	11	-	660	46	0.5	-	25	8
5	1.5	-	58	3	7	-	88	19
)	25	-	1900	500	5	-	174	89
)	11	-	380	66	4	-	193	42
	< 0.5	-	130,000	10	0.5	-	100,000	12
	< 0.5	-	7,400	30	< 0.5	-	8,000	18
	8	-	110	32	6	-	160	16
	11	-	7,400	90	6.5	-	8,000	48
	< 0.5	-	800	21	< 0.5	-	59	14
	0.5	-	3,300	8.5	3	-	480	19
.2	0.5	-	10	1	1	-	56	8
.5	7.5	-	200	12	1	-	82	9
	1.5	-	22	11	3	-	27	8

Table 18. Reduction of Salmonella senftenberg 775W in the process of cooking turkey rolls at various temperatures for four hours

Temperature °F of water bath	Average initial MPN per cm <sup>2</sup>	Average MPN after cooking per cm <sup>2</sup> per gram		Presence of <u>Salmonella</u> after cooking
130	1.1 x 10 <sup>6</sup>	4.6 x 10 <sup>4</sup>	1.1 x 10 <sup>6</sup>	+
140	1.2 x 10 <sup>6</sup>	< 0.3	2.3	+
145	1.4 x 10 <sup>7</sup>	< 0.3	< 0.3	-
150	1.3 x 10 <sup>7</sup>	< 0.3	< 0.3	-
160	4.6 x 10 <sup>6</sup>	< 0.3	< 0.3	-
170	7.8 x 10 <sup>6</sup>	< 0.3	< 0.3	-
180	4.3 x 10 <sup>6</sup>	< 0.3	< 0.3	-

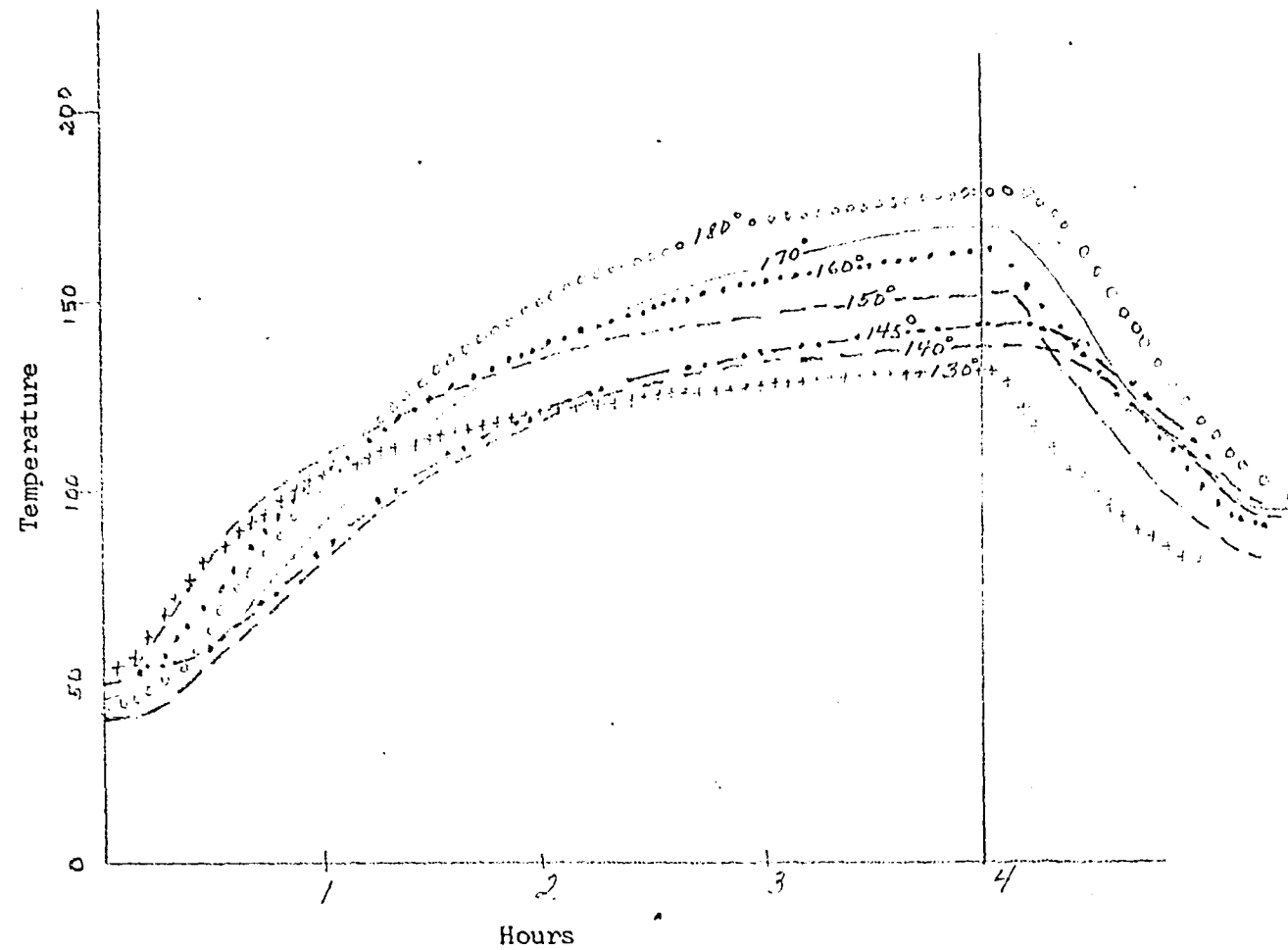


Figure. 2. Heating and cooling curves obtained when turkey rolls were cooked for four hours at various temperatures

Although over one million S. senftenberg organisms were inoculated, less than 0.3 cell per cm<sup>2</sup> or gram by MPN method were recovered when turkey rolls were cooked in water baths at temperatures of 76.6°C (170°F) and 82.2°C (180°F) and the cooking terminated at an internal temperature of 65.6°C (150°F) and 71.1°C and (160°F), although the white meat was often pink. In one sample 82.2°C (180°F) water and 71.1°C (160°F) termination, S. senftenberg was recovered when the whole roll was swabbed. With rapid cooling in running water containing ice, a temperature rise of 1-2°F was observed during the initial phases of cooling. The time that the internal temperature of the rolls was over a temperature of 60°C (140°F) exceeded 48 minutes in all cases (Table 19).

#### Plant evaluations

Temperatures of over 71.1°C (160°F) were reached when the turkey rolls were commercially cooked in water baths. Typical heating and cooling curves showing the internal temperatures of turkey rolls during cooking operations in plant equipment are illustrated in Figures 3 and 4. Heat penetration curves for these data are presented in Figures 5 and 6. These data were interpreted on the basis of the thermal death time curve with a z value of 11.8°F and a  $F_{140}$  of 78 minutes (from Angelotti et al. 1961b). Lethal rates were calculated, and this information is tabulated in Table 20 for thermal processing in Plant A and in Table 21 for thermal processing in Plant B. In the cooking operations carried out in Plant A, lethality was reached after the rolls were cooked for 196.8 minutes and when a temperature of 62°C (144.8°F) was reached. In Plant B, lethality occurred after 113.7 minutes and when a temperature of 64.5°C

Table 19. Reduction of Salmonella senftenberg 775W

Water bath temperature	Average initial MPN per cm <sup>2</sup>	Terminating internal temperature	Total cooking time (hours)	Final Rise on cooling†	Minutes above 140°F	Final MPN per cm <sup>2</sup>
170	2.5 x 10 <sup>6</sup>	150	2.8	151	62	< 0.3
	1.4 x 10 <sup>6</sup>	160	3.25	161	93	< 0.3
180	2.4 x 10 <sup>7</sup>	150	2.0	152	48	< 0.3
	2.4 x 10 <sup>6</sup>	160	2.12	161	64	< 0.3*

†Running water ice bath 40-50°F.

\*Swabbing entire roll yielded a positive sample.

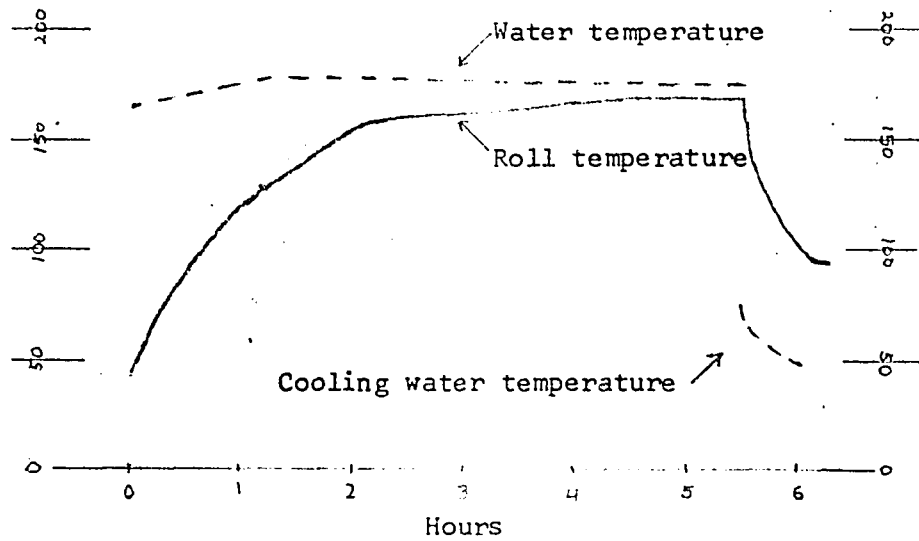


Figure 3. Typical heating and cooling curve for cooking turkey rolls - Plant A

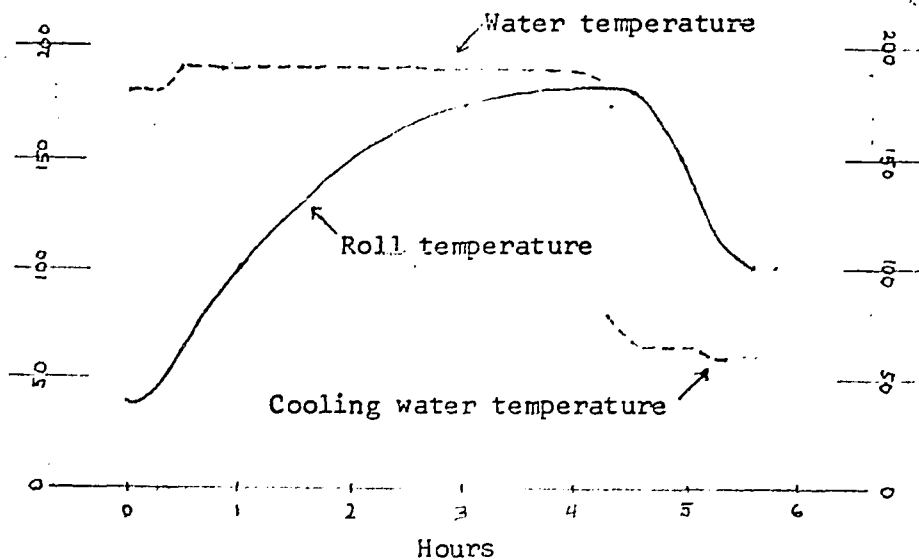


Figure 4. Typical heating and cooling curve for cooking turkey rolls - Plant B

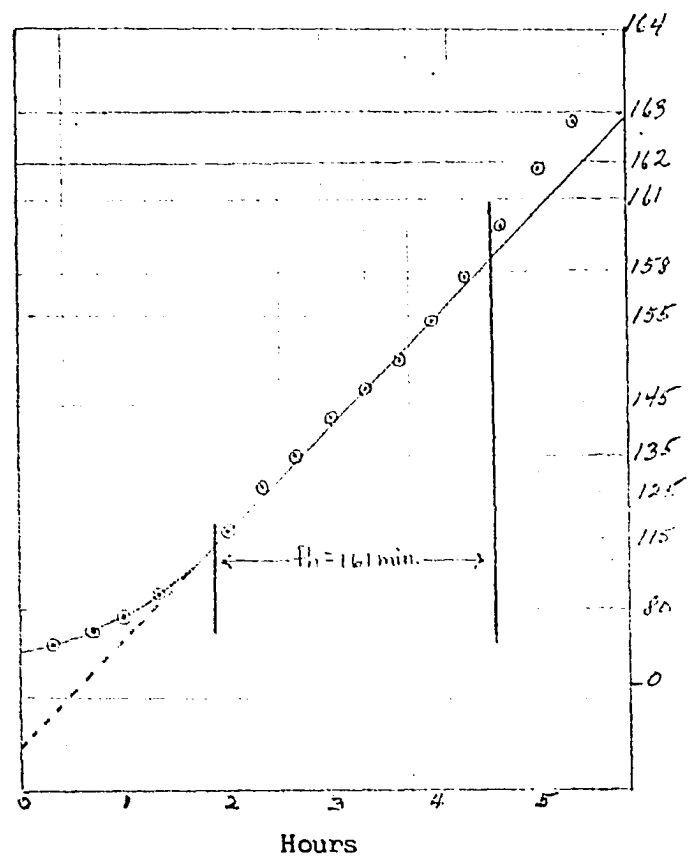


Figure 5. Heat penetration curve of cooking turkey rolls in Plant A

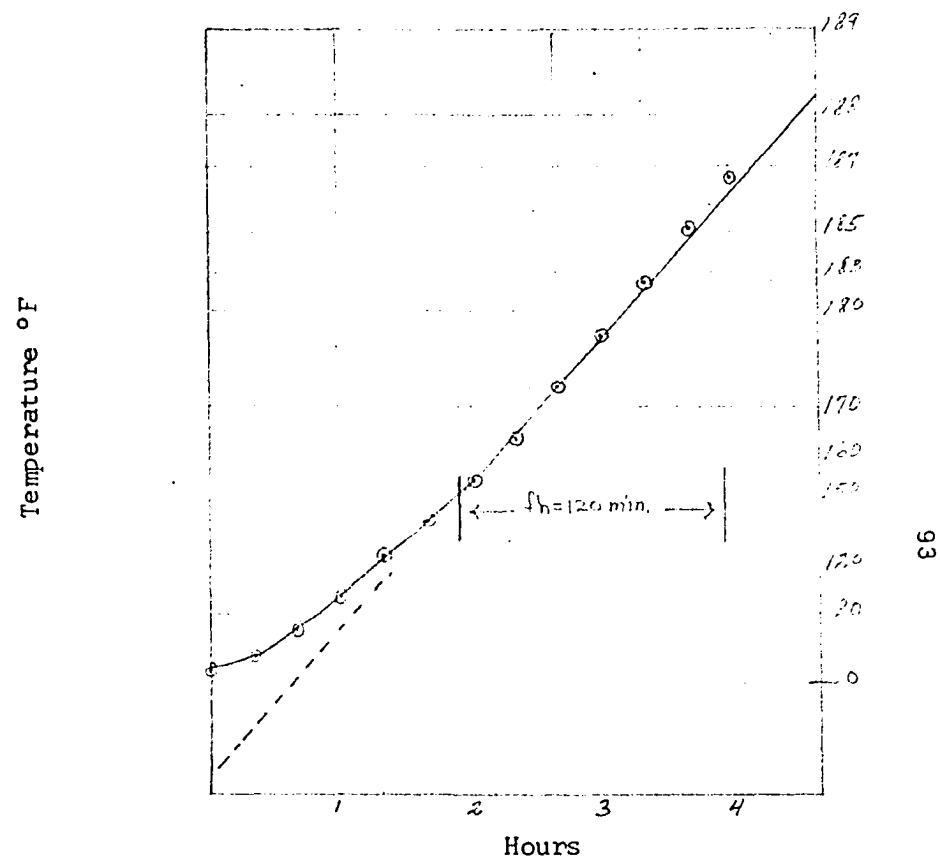


Figure 6. Heat penetration curve of cooking turkey rolls in Plant B



Table 20. Lethal rates for S. senftenberg 775W when turkey rolls were cooked in Plant A

Heating and cooling curve		Time necessary to destroy <u>S. senftenberg</u>		Cumulative rate (x interval of 20)	
Indicated time minutes	Corresponding temperature °F	minutes	Lethal rate		
120	117				
140	124				
160	133.5	280	.004	.08	
180	141.5	66	.015	.38	←
200	147.1	44	.042	1.22	
220	151.7	9.8	.102		
240	155	4.4	.227		
260	157.5	3.5	.290		
280	159	1.9	.527		
300	160.8	1.4	.714		
320	161.8	1.2	.833		

Table 21. Lethal rates for S. senftenberg 775W when turkey rolls were cooked in Plant B

Heating and cooling curve		Time necessary to destroy <u>S. senftenberg</u>		Cumulative rate (x interval of 10)	
Indicated time minutes	Corresponding temperature °F	minutes	Lethal rate		
80	122				
100	139	94	0.016	0.16	
110	145	29.5	0.034	0.50	←
120	153	7.5	0.133	1.84	
130	160	1.7	0.588		
140	165	0.68	1.471		
160	173	0.15	6.667		
180	178.3	0.06	18.182		
200	182	0.03	37.037		
220	184.6	0.02	58.824		
240	186.3	0.01	76.923		
260	170	0.26	3.846		
280	130	530			

(148°F) was attained.

Bacteriological evaluations of turkey rolls

Thirty-seven turkey rolls were evaluated after cooking and after freezing. Counts of total aerobic organisms ranged from less than one to 670 per gram. A median of 20 organisms per gram was calculated from the observed counts. Coliforms were recovered only once and in small numbers. Enterococci were recovered on three occasions and in small numbers. Salmonellae were not recovered from the cooked rolls, although they were isolated prior to cooking on several occasions (Tables 5 and 6). These results are tabulated in Table 22.

Table 22. Aerobic organisms, coliforms, and enterococci recovered from cooked turkey rolls

Plant	Number of samples	Total aerobic organisms per gram		Number of times isolated	Coliform	Number of times isolated	Enterococci
		range	median		Average count per gram (when isolated)		Average count per gram (when isolated)
A	15	< 1-670	40	1	4	3	2
B	13	< 1- 80	7	0		0	
C	9	< 1- 28	12	0		0	
Total	37	< 1-670	20	1	4	3	2

The diagram illustrates the transmission cycle of a disease, likely salmonella, between humans and turkeys. The cycle involves several key components and their interactions:

- Humans:**
  - Infected Humans:** Can transmit the disease to **Uninfected Humans** and **Uninfected Turkeys**.
  - Uninfected Humans:** Can be infected by **Infected Humans** and **Uninfected Turkeys**.
- Turkeys:**
  - Uninfected Turkeys:** Can be infected by **Infected Humans**, **Uninfected Humans**, **Infected Turkeys**, **Contaminated Feces**, **Air**, **Water**, **Soil**, and **Workers' Hands and Gloves**.
  - Infected Turkeys:** Can transmit the disease to **Uninfected Humans**, **Uninfected Turkeys**, **Contaminated Feces**, **Air**, **Water**, **Soil**, and **Workers' Hands and Gloves**.
- Food and Processing:**
  - Turkey Products:** Can be infected by **Uninfected Humans**, **Uninfected Turkeys**, and **Infected Turkeys**. It can also be contaminated by **Workers' Hands and Gloves** and **Kitchen Equipment**.
  - Other Foods:** Can be contaminated by **Kitchen Equipment** and **Workers' Hands and Gloves**.
  - Processing Equipment:** Can be contaminated by **Workers' Hands and Gloves** and **Uninfected Turkeys**.
- Environment and Vectors:**
  - Feed:** Can be contaminated by **Uninfected Turkeys** and **Infected Turkeys**. It is also a source of infection for **Uninfected Turkeys**.
  - Vectors (reptiles, insects, rodents, wild birds):** Can be infected by **Uninfected Turkeys** and **Infected Turkeys**. They can also transmit the disease to **Uninfected Turkeys**.
  - Contaminated Feces:** Can be contaminated by **Uninfected Turkeys** and **Infected Turkeys**. It is a source of infection for **Uninfected Turkeys**.
  - Air, Water, Soil:** Can be contaminated by **Uninfected Turkeys** and **Infected Turkeys**. They are sources of infection for **Uninfected Turkeys**.
  - Workers' Hands and Gloves:** Can be contaminated by **Uninfected Turkeys** and **Infected Turkeys**. They are sources of infection for **Uninfected Turkeys** and **Turkey Products**.
  - Kitchen Equipment:** Can be contaminated by **Workers' Hands and Gloves** and **Uninfected Turkeys**. It is a source of infection for **Other Foods**.
- Reproduction:**
  - Eggs:** Can be contaminated by **Uninfected Turkeys** and **Infected Turkeys**.
  - Incubator:** Can be contaminated by **Eggs** and **Uninfected Turkeys**. It is a source of infection for **Uninfected Turkeys**.
  - By-Products:** Can be contaminated by **Uninfected Turkeys** and **Infected Turkeys**.

Figure 7. The transmission of salmonellosis as related to turkeys and turkey products

### The Dissemination of Salmonellae

In this investigation certain aspects of the preceding cycle were studied. These are discussed in the following paragraphs.

#### Salmonellae in turkey feeds

Several studies have shown that poultry feeds were contaminated with Salmonellae (Erwin, 1955; Watkins et al., 1959; Morehouse and Wedman, 1961; and Boyer et al., 1962), and these feeds may provide a means for transmitting Salmonellae to turkeys (Boyer et al., 1962). Mixed feeds appear primarily to become contaminated from the protein ingredients such as fish meal, bone meal, meat scrap, feather meal, and animal protein (Watkins et al., 1959; Walker et al., 1961; Morehouse and Wedman, 1961; Pomeroy and Grady, 1961; Burr and Helmboldt, 1962; U.S. Department of Health, Education, and Welfare, 1964 and 1965; and Magwood, 1965).

Whereas most of the studies dealing with the presence of Salmonellae in feeds were conducted with samples obtained from manufacturers or with ingredients, this investigation dealt with feeds from farm sources, some of which were subject to contamination. Due to the nature of these sources, factors other than the feed itself must be considered in the interpretation of the findings. Some of the samples were obtained from bins which were subject to contamination by insects or rodents. The samples obtained from feeders were exposed to contamination by workers, rodents, and occasionally by the turkeys. Multiplication could have occurred in the feeds that were exposed to the elements. Besides farm contamination, for instance, natural die off due to storage in elevators

or at farms could have altered the results. Leistner et al. (1961) in studying pig feeds, noted a drastic reduction in incidence of Salmonellae in commercial feed samples obtained from farms (13%) as compared to samples of rendered animal by-products (61%). Thus, the samples collected in the present investigation represented the risk passed to turkeys from consuming feeds.

The serotypes isolated from feeds during this investigation have been frequently recovered from animal feeds by other investigators (U.S. Department of Health, Education, and Welfare, 1964 and 1965). Six of the seven different serotypes found in feeds were also isolated from dead turkeys upon autopsy or from fecal droppings as well as from turkey meat and from the environment of processing plants. Only once was a multiple recovery obtained from a sample. When Jacobs et al. (1963) examined the entire contents of 30 bags of fish meal, S. typhimurium, the most frequently encountered serotype from man and animals but not the most frequent isolate from feeds and feed ingredients, was recovered from 27% of all bags and from 57% of the bags in which Salmonellae were found. When they obtained five 10 gram samples from seven bags, no Salmonellae were isolated. A subsequent examination of the entire bag contents showed that six of the seven bags were contaminated with Salmonellae. Thus, if larger samples were analyzed, additional serotypes may have been recovered. This may, in part, explain why S. san diego, the most frequently recovered serotype in this investigation, was not isolated from feeds. The methods used in the isolation may have also influenced the recovery.

An interesting observation was made of a turkey flock in which

five serotypes (S. bredeney, S. manchester, S. muenchen, S. newport, and S. saint paul) were isolated from fecal droppings obtained from a delivery truck. Two of these serotypes (S. bredeney and S. muenchen) were recovered from the feeder located in the turkey shed on the same day that the isolations were made from the droppings. On another occasion, S. anatum was recovered from a feed sample and from fecal droppings that were obtained from the same farm during a sampling visit.

Since the feed samples taken were sometimes subject to contamination from dust, rodents, and insects, as well as the turkeys themselves, commercial feeds could not be definitely incriminated as the source of Salmonellae for the turkeys and subsequently for the human food; however, feeds which turkeys consumed at farms were found to be contaminated with Salmonellae and thus a potential source of infection.

#### Salmonellae in water troughs

The source of infection of the first turkey or first group of turkeys in a flock remains an enigma. These turkeys could have become contaminated via eggs, the hatchery environment, feeds, fomites, farm workers, or the farm environment. However, once the infection has been introduced into the flock environment, contamination of water troughs by contaminated feed, down, dust, or feces is a possibility. The results of this investigation indicate that this situation frequently occurs on the farm. Gauger and Greaves (1946c) showed that drinking water could become contaminated and remain so for several weeks in an environment maintaining artificially infected turkeys. The present investigation indicates that the same situation occurs in naturally infected flocks. The troughs

holding the water offered little protection from contamination. Some had diversion guards which did not extend over the entire drinking area, and turkeys often perched on these guards. Other troughs had a swing bar to prohibit the turkeys from perching over the water; however, these were not entirely satisfactory. Still other troughs had no protection from the birds. Even with some of the better operations, these water troughs were not flushed out more than once a day in the brooder houses and seldom on the range. The water frequently contained feed, fecal material, and debris, and it was occasionally cloudy. The water, after sampling, was sometimes allowed to stand at room temperature overnight and increased turbidity and microbial growth was evident.

The serotypes of Salmonella isolated from the trough water were frequently the same types as were recovered from fecal droppings. Thus, water cannot be overlooked as an important vehicle for the transmission of Salmonellae. The water supply was usually from a protected source, but the drinking troughs were unprotected from overhead contamination and frequently were constructed so as to invite turkeys to perch overhead. Water troughs probably served as a medium for bacterial multiplication as well as a vehicle for transmission of Salmonellae to many turkeys in the flock.

The occurrence of Salmonellae in fecal droppings when turkeys arrived at processing plants

This study has shown that turkeys are frequently infected with Salmonellae on the farms, and turkeys are carriers of these organisms when birds are transported to the processing plants. Since turkeys have



the habit of picking the ground and come in close contact with other turkeys, the fecal-oral route of transmission of Salmonellae is conceivable.

During the excitement of being loaded on trucks and transported to the processing plant, turkeys frequently defecate. During transit and while waiting to be unloaded, turkeys are in close contact and often slip and fall on fecal material. Thus, their feet and body parts are exposed to feces just prior to slaughter. If one or more fecal carriers of Salmonellae are placed in the same cage with noninfected turkeys, transmission of Salmonellae by direct contact or by contaminated feces could readily occur.

#### Tracing Salmonellae from farm to plant

This phase of the project was difficult to analyze since turkey flocks frequently carry several different serotypes; however, certain trends were revealed.

The introduction of S. typhimurium into the plant was observed after Flock B (Day I) entered the plant. Its source appeared to be from the turkeys as indicated by the recovery of this serotype from fecal droppings at the farm. This serotype persisted in the plant or was reintroduced during the next two days, but was isolated only once thereafter. Later in the day, S. cerro was recovered from most of the equipment as well as from turkey meat. Although the source of this organism was not determined, evidence, as indicated in Day I of Table 13 by the sudden appearance of this serotype, suggested that its origin was Farm C. This serotype was isolated twice from equipment on the following day but not from the plant subsequently. The following day (II) S. san diego

appeared in the plant. This organism was recovered from the farm as well as from droppings of birds arriving at the plant. S. san diego was recovered on the next two days. On the latter day this serotype was recovered after clean-up operations. S. san diego appeared on several occasions thereafter and was, perhaps, reintroduced since a lapse of a week and two sample visits intervened between isolations. Also, it is a common serotype found in turkeys. On the third day (III) S. newington was introduced into the plant, probably from Flock E, where it was isolated from droppings and from water. S. anatum could have been reintroduced from Flock F (previously isolated from Farm F), or perhaps it remained in the plant from a previous entry.

Two weeks later, (Day VI), S. muenchen and S. saint paul were recovered from droppings of birds entering the plant and also on carcasses and on equipment. S. anatum reappeared, probably from Flock I where it had previously been isolated from fecal droppings on the farm. After clean-up at the end of the week, no Salmonellae were isolated. On the first day of the next week (X), only S. anatum reappeared on carcasses and in the picking environment. Evidence for its origin came from recoveries of this serotype from trough water and fecal droppings on the farm and on truck beds.

Recoveries of any serotype from a particular piece of equipment in the picking, eviscerating, or packaging areas were not made on more than three consecutive days. After this period, these bacteria were removed by effective cleaning, diluted sufficiently so as to be undetected, or replaced by other serotypes.

Due to the limitation of the procedure of picking only a few

suspected colonies on each plate (a maximum of six), the complete tracing of serotypes may have been biased. However, ample evidence was uncovered to show the importance of the incoming flock in bringing Salmonellae to the processing plant and disseminating them to the plant environment.

The role of plant equipment in the dissemination of Salmonellae

The spread of Salmonellae begins on the farm or in trucks and continues with the processing of the carcasses. In previous studies, Salmonellae have been isolated from the picking room equipment (Browne, 1949; and Galton et al., 1955), and from the eviscerating room equipment (Galton et al., 1955; Kyle et al., 1952; Brobst et al., 1958; and Gunderson et al., 1954). The findings in this investigation revealed Salmonellae on the surfaces of equipment in both of these areas as well as from equipment in the "further processing" rooms at both plants.

Clean-up procedures (water flushing, washing, and steaming) used in the two plants were not entirely adequate to completely eliminate Salmonellae from the contact equipment. However, if inadequate sanitation was of prime importance in the dissemination of Salmonellae, build-ups on particular equipment should have been observed, and one serotype should have predominated over a long period of time. This was not the case. A serotype once introduced into a plant could be recovered only for a few days. The most important source of Salmonellae for the turkey products was contaminated incoming turkeys. However, after pieces of equipment had been used to process infected turkeys, they appeared to serve as a means of transmitting Salmonellae to uninfected turkeys.

Several studies have shown that Salmonellae may survive on surfaces

for long periods of time (Pomeroy and Fenstermacher 1939, and Orr and Moore 1953). However, McDade and Hall (1964) found that S. derby could not be recovered from surfaces (glass, ceramic tile, polished stainless steel, asphalt tile, and rubber tile) after 48 hours of exposure to 25°C and 53 or 85% relative humidity, although these organisms were recovered after 17 days when exposed to 25°C and 11% relative humidity. This last study may help explain why Salmonella serotypes were recovered for only a few days after they were introduced into the plant.

Many items of equipment found in the plants, even those of new design, appeared to aid in the dissemination of Salmonellae. Carcass contact surfaces (fingers, edgings, and bars) of defeathering machines were frequently contaminated with Salmonellae as were the carcasses after they were roughed and picked by these machines.

This study has shown that these pieces of equipment are important in the dissemination of Salmonellae to the turkey meat. Some of this transmission is transient in nature and is removed during spray washing operations; however, Salmonellae still remained on some of the carcasses after washing. In addition to exposure to contamination from fingers, from metal sheeting which carcasses contact on entry and exit from pickers, and from support bars that carcasses drag across in straight-line defeathering machines, carcasses are exposed to direct contact with fecal matter and feather debris on the metal chute and sides as well as with the rubber partitions and fingers in automatic spiral picking machines.

Considering the force at which the carcasses are conveyed through the spiral pickers and with the whipping action of the fingers,

Salmonellae present on contact surfaces of these items of equipment could foreseeably be rubbed into the meat tissue so as to make removal by spray washing difficult. However, additional work is needed to evaluate tissue penetration. The vigorous nature of picking operations are such that leakage of feces from the relaxed anus is possible and even inevitable. In hock pickers, the posterior of the carcasses and the legs were conveyed across metal guards which were smeared with fecal material.

Chutes and tables and other such equipment in the picking and eviscerating rooms appeared to be ideal for the mechanical transmission of Salmonellae from contaminated carcasses to uncontaminated carcasses. The surfaces of tables contained water mixed with blood, fecal material (in the case of picking room tables), fat, and bits of tissue. Bacterial growth in this medium is conceivable. Since these surfaces are not cleaned until the end of the day's operation, bacterial build up due to continued addition of contamination or due to growth would be likely. In general, the highest percentage of recoveries of Salmonellae were from equipment in the picking environment. The percentages generally declined in the eviscerating environment and in the whole bird packaging area. A higher percentage of recoveries was once again observed in the "further processing" environment. Isolations of Salmonellae from turkey meat followed this same trend.

With regard to equipment in the "further processing" area, there is evidence that contact with this equipment after it has become contaminated, is one of the factors causing the statistically significant increase in isolations observed between the chilled, eviscerated carcasses, and the finished products in Plant B and the increased recoveries from

the finished products in Plant A. Most all items of equipment used in the "further processing" areas were contaminated to some extent during processing. Equipment, such as line tables, conveyors, saws, and scales, that contacted almost all of the turkey meat in Plant B were frequently found to harbor Salmonellae.

Thus, dissemination from infected to uninfected carcasses as a result of contacting equipment during processing is indicated from the results of this investigation.

The role of the food processing worker in the dissemination of Salmonellae

Browne (1949), Kyle et al. (1952), Gunderson et al. (1954), and Dixon and Pooley (1961) recovered Salmonellae from the hands or gloves of workers when swabs were employed. By having workers rinse and scrub their hands or gloves, Salmonellae were recovered from approximately 30% of the samples. This procedure resulted in higher recoveries than those reported by the above investigators. No differences were observed between the workers' bare hands or their gloves. The serotypes recovered from the workers were, for the most part, the same as those isolated throughout the plant, including isolations prior to contact by the workers. It was, therefore, felt that the isolated Salmonellae came primarily from the partially processed carcasses, and that workers served mainly as mechanical transmitters of these organisms. Recoveries from workers from Plant B occurred only when over 50% of the total samples from equipment and turkey meat were positive. In Plant A, recoveries were made only when over 11% of the total samples were positive. On some occasions, isolations of Salmonellae were not made until the meat had been handled

by the workers. This may have been due to workers being carriers, or being previously exposed to another flock while engaged in picking or evisceration activities (Plant A). When isolations were not numerous, chance could have influenced the results. The human carrier may be important shortly after coming to work or after returning from a break, but after contact with turkeys for a period of time the flora on carcasses and hands probably becomes similar. In the study by Gunderson (1954), the only serotype isolated from hands were S. pullorum, a serotype which is host adapted to chickens. This observation indicated the importance of the incoming turkeys as the source of contamination and the workers as a mechanical transmitter.

Nevertheless, the human carrier should not be overlooked. Edwards (1958) suggested that the carrier state is an occupational hazard to those who continually handle uncooked meat and carcasses. He (1963) further pointed out that the presence of Salmonellae in foods and on carcasses with which the food handler is in continuous contact, predispose the worker to the carrier state. The repeated ingestion of small numbers of Salmonellae or the failure to remove these organisms from hands or finger nails by washing may result in turkey plant workers becoming carriers. In their food preparation tasks at home or at social functions, the workers impose a potential risk to the community. Galton et al. (1964b) mentioned that it is difficult to determine if the food handler is the source of infection or has been infected from the same source as the victims of an outbreak.

Edwards (1958) cautioned that when salmonellosis have been transmitted through the medium of such foods as coconut (Mackenzie, 1953),

dried yeast (Kunz and Ouchterlony, 1955), soya milk, and smoked fish (Olitzky et al., 1956) in which Salmonellae are not indigenous, the role of the human carrier in the processing plant becomes increasingly apparent. Edwards (1958) further stated that the systematic and frequent examination of food handlers should extend not only to workers in food dispensing establishments but also to those in food processing plants as well, and that any individual exhibiting any symptom of intestinal infection should be prevented from handling food until it is established that pathogenic bacteria cannot be demonstrated in his stools.

#### Contamination of turkey meat during processing operations

In Plant B, the difference between the carcasses after picking and the carcasses after washing, before icing, and before packaging was significant ( $P < 0.01$ ). No difference was observed between the last three stages of processing ( $P > 0.05$ ). Evidence was shown to suggest that picking equipment was important in spreading Salmonellae from carcass to carcass. Spray washing procedures appeared to be effective in reducing the contamination level; however, this procedure failed to eliminate Salmonellae from carcasses. After evisceration, internal and external spray washing, and spin chilling, the number of carcasses harboring Salmonellae continued to decrease although the decrease was not statistically significant. An increase in the percentage of isolations of Salmonellae was observed after the carcasses were chilled overnight and conveyed to a grading and packaging table; however, this increase was not statistically significant when compared to the previous processing steps.



In Plant A, samples positive for Salmonellae increased from 11.2% for chilled, eviscerated carcasses to 20.5% for finished products. This difference was not significant ( $P > 0.05$  but  $< 0.10$ ).

In Plant B, the difference between the chilled turkey carcasses before "further processing" operations and the finished products was significant ( $P < 0.05$ ). The reason for this difference is believed to be due to the fact that chilled carcasses disseminated Salmonellae to equipment, utensils, and workers which, in turn, transmitted these organisms to other pieces of turkey meat. In this operation, certain pieces of equipment (saw, conveyor, scales, tables, and automatic tying machine) contacted each turkey carcass or product. Salmonellae were frequently isolated from these items of equipment. The difference between the finished products in Plant A and the finished products in Plant B was significant ( $P < 0.05$ ). This difference is difficult to explain; however, the increased contamination in Plant B may have resulted from such equipment as the spiral automatic picker, the chute, the picking room table, and the trussing table. All of these pieces of equipment frequently harbored Salmonellae, and each carcass had intimate contact with the surfaces. Another difference in equipment was that Plant B employed spin chilling although these machines were found to harbor Salmonellae infrequently. A difference in operation is also noteworthy. Since most of the choice turkeys processed in Plant B were packaged as whole birds, sometimes inferior carcasses were sent to the "further processing" room, whereas in Plant A, all the turkeys were prepared into cut-up products. Another explanation of this difference could be the influence that the incoming flocks imposed. Since flocks

supplying Plant A were not studied, this could not be evaluated.

More Salmonellae were found on the chilled, eviscerated carcasses than on the thawed, eviscerated carcasses during the present investigation; yet, the difference was not significant at the .05 level. Total isolations within the plants were higher during the processing of freshly killed turkeys. This trend was particularly evident in Plant B. Schneider and Gunderson (1949) reported a statistical significant difference between chilled chickens and thawed chickens in regard to the presence of Salmonellae.

Salmonellae were isolated from 27.4% of the finished "further processed" products that were produced by both plants and from 17.3% of the packaged whole turkeys produced in Plant B. The former is similar to the findings of Woodburn (1964), and the latter is similar to the findings of Wilson et al. (1961). The results in the present investigation were higher than those of the previous investigations of Schneider and Gunderson (1949), Felsenfeld et al. (1950), Galton et al. (1955), and Tailyour and Avery (1960). It should be pointed out that most of these studies involved chicken meat and, therefore, are not directly comparable to turkey meat.

The public health aspects of the presence of Salmonellae on the finished turkey products may involve turkeys directly or indirectly. Turkey products contaminated with Salmonellae are potential sources of outbreaks if these products are improperly refrigerated or inadequately cooked. Turkey meat may also serve to convey Salmonellae to kitchen equipment or to workers' hands and, thus, indirectly contaminate potentially hazardous foods which are not subsequently cooked. According to

Newell (1959), the most important role of food in the spread of salmonellosis is its ability to act as a vehicle which will carry organisms from animal to kitchen or factory. When food takes this role, the presence of a small number of Salmonellae is almost as dangerous as the presence of large numbers. Thus, one food (such as turkey) may act as a means of introducing Salmonellae to a food preparation establishment, and another, after contamination from the first, may act as the medium for growth and subsequently as the product causing illness.

The recoveries of Salmonellae were probably not complete. Leistner et al. (1963) reported that two enrichment media increased the number of recoveries. Jacobs et al. (1963) found that larger samples greatly increased the number of recoveries as well as the number of serotypes. Woodburn (1964) showed the value of increasing the incubation temperature to 43°C, and Curbelo and Marquez (1954) pointed out the value of increasing enrichment incubation time. The results of this study possibly represent an underestimate of the number of positive samples due to the limitations of the methods employed.

#### Significance of the isolated serotypes

In the following paragraphs each of the Salmonella serotypes that were isolated are reviewed in alphabetical order. The discussion centers around the isolations made during this study, the past and present status of each serotype, and outbreaks traced to these serotypes.

S. anatum was the second most frequently isolated serotype during this investigation. It was recovered from feed, trough water, turkeys,

turkey feces, turkey meat, processing equipment, and workers' hands and gloves. In regard to previous isolations of this organism, S. anatum was one of the five most common serotypes isolated from animals and one of the seven most common isolates from humans in the United States from 1934-1963 (Galton et al., 1964b; and U.S. Department of Health, Education, and Welfare, 1964). In 1963, S. anatum was the sixth most frequently isolated serotype from turkeys, and the second most commonly recovered serotype from animal feed. Similar recoveries have been made in Canada (Bynoe and Yurack, 1964). In regard to poultry related outbreaks, S. anatum and three other serotypes were isolated from patients having gastroenteritis following the consumption of stuffed turkeys (Miller and Condit, 1964).

S. binza was recovered from processing equipment and from trough water. This serotype is an infrequent isolate from man, but it has been recovered rather often from mixed poultry feed, meat scraps, and fish meal. In both the United States and Canada in 1963, S. binza was isolated from fowl, feed, water, and humans. Over half of the isolations were from turkeys (Bynoe and Yurack, 1964; and U.S. Department of Health, Education, and Welfare, 1964).

S. blockley was isolated from turkey meat, contact equipment, and workers' hands. This serotype was first seen in 1955 (Friedman et al., 1955) and since then has established itself as one of the more frequently encountered serotypes. Although this organism is usually recovered from chickens, it is also commonly found in turkeys (Moran, 1961; U.S. Department of Health, Education, and Welfare, 1964 and 1965). An outbreak associated with poultry was reported by McCroan (1963).

S. bredeney was recovered from feed, trough water, turkey feces, turkey meat, and contact equipment. This serotype was the sixth most commonly isolated serotype from animals during the period 1934-1947 (Galton et al., 1964b), and the fifth most frequently recovered serotype from turkeys in 1963 (U.S. Department of Health, Education, and Welfare, 1964). In the United States in 1964, 2% of non-animal isolations and 1% of human isolations were of this serotype (U.S. Department of Health, Education, and Welfare, 1965). Also, isolations from feed have been reported. Roast turkey was implicated in a family outbreak involving eight people in New York (Fodor, 1964).

S. cerro was isolated from feed, turkey meat, contact environment, and finished products. It was the third most commonly isolated serotype from the processing plants, and it was found on 11 occasions.

S. cerro is a rare serotype. It was not reported from turkeys between 1957 and July, 1961 (Moran, 1961). In 1963, 44% of the recoveries were from animal feeds, usually poultry feeds, although six human isolations were also reported. These results may indicate the continuation of a cycle in which Salmonellae are perpetuated from feeds to turkeys and finally showing up in turkey meat and in processing plants.

S. chester, which has a close antigenic relationship to S. san diego, was recovered from all sources studied (feed, trough, water, turkey feces, turkey meat, contact equipment, workers' hands, and finished products). It was isolated during 15% of the plant visits. During the period 1957-1961, S. chester was the ninth most commonly isolated serotype from animals (Moran, 1961). In 1963, it was the seventh most commonly recovered serotype from turkeys, and 1% of the human isolations were due to this

organism. Isolations from feed have also been reported (U.S. Department of Health, Education, and Welfare, 1964). In 1964 in Wisconsin, 95% of the cases involving turkeys on 30 farms were caused by S. chester (Baker, 1964). Between 1963-1964, 11% mortality was reported in turkeys in six Minnesota flocks from this serotype (Olson, 1964). In regard to Salmonellosis caused by S. chester, a human outbreak due to turkey meat was reported by Sanborn (1963), and an outbreak due to chicken salad was reported by Andelman (1963).

S. derby was isolated four times during this investigation. In the period between 1934-1958, this serotype ranked sixth as a cause of human illness and then dropped to below twelfth place (Galton et al., 1964b). During 1963 and 1964, it rose to second place primarily due to isolations resulting from hospital associated outbreaks initially caused by cracked eggs (U.S. Department of Health, Education, and Welfare, 1964 and 1965). It accounted for 23.8% of the human deaths associated with salmonellosis in 1963. During 1963, 25% of the non-human isolations were from turkeys. Heavy losses in young chickens and turkeys have been reported in Canada (Bynoe and Yurack, 1964). S. derby was recovered from two cases in which turkey rolls were incriminated as the food responsible for the illness (U.S. Department of Health, Education, and Welfare, 1963).

S. give was isolated on one occasion from Plant B. Over 80% of isolations from non-human sources in 1964 were from fowl (U.S. Department of Health, Education, and Welfare, 1965). Most of these recoveries were from turkeys. Currently, it is a cause of sporadic human cases; however, in the period 1934-1947, it was the eleventh most commonly isolated serotype from humans (Galton et al., 1964b). During the years 1947-1958,

the source of this serotype was from poultry and eggs in 95 of 285 isolations.

S. halmstad was recovered from trough water and fecal droppings. It is a very rare serotype which was first isolated in 1958 in Sweden from imported meat-flour. An isolation from a human was reported in Michigan in 1964 (U.S. Department of Health, Education, and Welfare, 1965).

S. heidelberg was isolated from trough water and turkey feces. This serotype first appeared in the United States in 1954, and by 1958, it ranked as the seventh most commonly reported serotype from animals. During the period 1954-1958, over half of the isolations were from poultry and eggs. In 1963, it became the third and second most common Salmonella serotype isolated from human and non-human specimens, respectively. During this same year, it was the second most common isolate from turkeys (U.S. Department of Health, Education, and Welfare, 1964). Turkey served at a banquet was responsible for 78 cases of salmonellosis caused by S. heidelberg (Vancouver, British Columbia, Metropolitan Health Service, 1962).

S. infantis was recovered from turkey meat and contact equipment. In 1963, this serotype was the fifth most common serotype isolated from humans and the third most common one isolated from non-human sources. It ranked ninth as an isolate from turkeys. Furthermore, it was a common isolate from animal feeds (U.S. Department of Health, Education, and Welfare, 1964). In an outbreak due to S. infantis, involving 164 people, turkey and dressing were found to be responsible (Janney, 1962).

S. kentucky was recovered from contact equipment and a worker's hands

during one plant visit. Isolations in 1963 included fowl, feed, and humans (U.S. Department of Health, Education, and Welfare, 1964).

S. manchester was isolated from turkey fecal droppings. It has rarely been isolated in the United States, but it was the third most common serotype isolated from humans in Germany in 1959.

S. manhattan was recovered from turkey meat on one occasion. It accounted for approximately 1% of the human isolations in 1963, and 72% of the non-human recoveries were from turkeys. In 1964, 42 of 47 isolations were poultry associated (U.S. Department of Health, Education, and Welfare, 1964 and 1965). This serotype was responsible for an outbreak in which turkey rolls were incriminated (Freitag et al., 1963).

S. montevideo was recovered on one trip to Plant B. In the United States in 1963 and 1964, S. montevideo was the fifth ranking Salmonella isolation from non-humans, and the tenth ranking Salmonella isolation from humans (U.S. Department of Health, Education, and Welfare, 1963 and 1964). Most of the non-human isolations were associated with poultry. It is reportedly a common isolate from feed, and during this investigation was found in a feed sample. Turkey meat and dressing were incriminated as a vehicle of S. montevideo in a factory outbreak (Belden, 1964).

S. muenchen was recovered from all the sources investigated in this study. This serotype appeared in the list of the top ten serotypes from human and animal sources during 1934-1958 (Galton et al., 1964b). Half of the non-human isolations in 1964 were from poultry. It is a common human isolate in the Netherlands (U.S. Department of Health, Education, and Welfare, 1964 and 1965). This serotype was implicated in an outbreak



possibly involving turkey rolls (Fish, 1963).

S. muenster was isolated on two consecutive sampling trips from turkey meat and contact equipment in Plant A. This is an extremely rare serotype, with most of the recoveries coming from the Southern United States. An isolation from a turkey in Minnesota was reported in 1964 (U.S. Department of Health, Education, and Welfare, 1965).

S. newington was recovered from trough water, fecal droppings, contact equipment, and finished products. Twenty-four of 39 non-human isolations were from poultry in 1964 (U.S. Department of Health, Education, and Welfare, 1965). S. newington and S. poona were responsible for an outbreak of salmonellosis involving 88 of 129 persons that attended a wedding reception. These organisms were isolated from a turkey served at the reception (Bisell, 1963).

S. newport was isolated from turkey feces, turkey meat, contact equipment, and finished products. Only nine isolations were made, but the organism was recovered on five occasions. In 1964, S. newport was the fifth most common isolate from man; in 1962-1963 it was ranked third; and in the period 1934-1958 it ranked second. In 1964, S. newport was the tenth most frequent isolate from non-humans (U.S. Department of Health, Education, and Welfare, 1965), and it ranked in the first ten from 1934-1947 (Galton et al., 1964b). S. newport has been transmitted to man by turkey meat on several occasions (Smith, 1963; and Miller, 1964).

S. oranienburg was recovered from a meat scrap and bone meal sample. It has often been reported as one of the first ten isolates in both man and animals since 1934 (Galton et al., 1964b). In 1964, it comprised 2.6% of human and 2.9% of all non-human isolations. Isolations are

common from poultry meat and eggs as well as from feed and feed ingredients. Most of the animal isolations in 1964 were from turkeys (U.S. Department of Health, Education, and Welfare, 1965).

S. pullorum was isolated from contact equipment on one of the sampling trips to Plant A. Traditionally, S. pullorum has been associated with poultry, particularly chickens. Four human isolations were reported since 1962 (U.S. Department of Health, Education, and Welfare, 1964 and 1965).

S. reading was isolated from contact equipment, a worker's hands, and from a finished product. This organism is sporadically isolated from man and animals. In 1958, it was responsible for an interstate outbreak in which the vehicle was not identified. However, during this period recoveries from poultry also increased.

S. saint paul comprised the fifth most commonly recovered serotype during this investigation. It was isolated on over 16% of the sampling trips. Since 1957, S. saint paul has been one of the ten most commonly isolated serotypes from animals and, since 1962, from humans. In 1964, for instance, it comprised 3.1% of human isolations and 3.5% of non-human isolations (U.S. Department of Health, Education, and Welfare, 1965). Undercooked turkeys were responsible for an outbreak of salmonellosis due to S. saint paul (Condit and Link, 1962).

S. san diego was the most frequently isolated serotype during this investigation. It topped the list of isolates from both plants, and it was recovered on 30% of the sampling trips. Turkeys accounted for 82% of the isolations of this serotype and from non-human sources in 1964 (U.S. Department of Health, Education, and Welfare, 1965). Isolations

were neither reported from feed or ingredients in 1964, nor were they recovered from these sources in this study. S. san diego gastroenteritis affected approximately 1000 people attending a Christmas dinner. Turkeys which were insufficiently cooked were the responsible vehicles in this outbreak (Mollohan and Cross, 1965).

S. schwarzengrund was recovered from the plant environment, workers' hands, and turkey meat as well as from the finished products. S. schwarzengrund isolations are frequently made from poultry, particularly turkeys, as well as from man. An outbreak caused by this serotype was traced to turkey dressing (Dougherty, 1963).

S. senftenberg was recovered from a feed sample and from turkey fecal droppings. Isolations of this serotype usually have been reported from poultry, eggs, animal feed, and fertilizers (U.S. Department of Health, Education, and Welfare, 1963 and 1964).

S. stanley was recovered on three consecutive days in the environment of Plant B. This is a rather rare serotype in the United States, although it was reported as the second most common serotype in the Netherlands in 1962. In the past, isolations from turkeys have been reported; for instance, in 1964 an isolation from a turkey was made in Iowa (U.S. Department of Health, Education, and Welfare, 1965).

S. tennessee was isolated from turkey meat and equipment during the processing of frozen turkeys and also a week later on a subsequent visit to the plant. This serotype has been in the first ten list of common types, recovered from humans, during 1934-1958 (Galton et al., 1964b). In 1964, it was isolated from 1.6% of human and 2.1% of non-human

specimens (U.S. Department of Health, Education, and Welfare, 1965).

Turkey isolations are not infrequent.

S. typhimurium was the fourth most common isolate during this investigation. It was recovered on 24% of the plant visits. In the United States, S. typhimurium was the most frequently isolated serotype from both man and animals since 1934 (Galton et al., 1964b). In fact, in most countries throughout the world it is reported as the predominant serotype. In 1964, it ranked first in the number of isolates from turkeys, accounting for 15.5% of the isolations (U.S. Department of Health, Education, and Welfare, 1965). Innumerable turkey-related outbreaks have been described (Mackel et al., 1959; Sanborn, 1963; Ager, 1962; and Sanders et al., 1963).

S. worthington was isolated from three dead turkeys. The following year, during an outbreak of salmonellosis in young poults, it was isolated from two dead birds and from fecal droppings obtained from the same farm. No isolations were made from samples of feed procured at this farm. Historically, this serotype was first isolated from a turkey in Minnesota (U.S. Department of Health, Education, and Welfare, 1965). In 1964, it represented 1.1% of the human isolations, and 39 of 61 non-human isolations of this serotype were from poultry.

Arizona 7:1,7,8 was isolated during one visit to Plant A. Although Arizona serotypes were not sought during this investigation, their recovery should not go unreported. This serotype has frequently been the cause of outbreaks in turkeys. It was also responsible for a human outbreak involving 23 persons. Chocolate eclairs were the incriminated food (Edwards et al., 1959).

All of the serotypes isolated during this investigation have been recovered from humans, although some of them infrequently. Most of the serotypes recovered have also been involved in human outbreaks, and several of these outbreaks have been caused by turkey products.

#### Comparison of Bacterial Counts

The bacterial counts evaluated were obtained from only one 10 cm<sup>2</sup> area from each of the carcasses or each of the finished products surveyed, and because of this a variation would be expected and was observed. When a t-test, based on the hypothesis that two populations have the same mean and  $\sigma^2$  not known (Dixon and Massey, 1957) was applied to the log of the means, the following conclusions were obtained:

The difference between the log of the mean of the total aerobic count for the chilled, eviscerated carcasses and the log of the mean of the total aerobic count for the finished products at both plants was not significant ( $P > 0.05$ ). Since the plates were incubated at 30°C, this should have allowed for the growth of many psychrophiles as well as mesophiles. From these results, it did not appear that there was significant multiplication during the processing of "further processed" turkeys. However, difference in the contamination level on the various surfaces of the meat could also have influenced the results. The difference between the log of the mean of the coliform counts for the chilled, eviscerated carcasses and the log of the mean of the coliform counts for the finished products at both plants was significant ( $P < 0.05$ ). Workers could have contributed to the build up as well as improperly cleaned equipment;

however, isolations of Salmonellae did not bear out this same relationship.

The difference between the log of the mean of the enterococcal counts for the chilled, eviscerated carcasses and the log of the mean of the enterococcal counts for the finished products at Plant B was significant ( $P < 0.05$ ). However, a similar relationship was not observed when comparisons were made with data from Plant A.

No correlation was observed between the bacterial counts and the recovery of Salmonellae.

#### Thermal Processing of Turkey Rolls

When turkey rolls were cooked by the procedures employed at the two plants studied during this investigation (water bath at 165°F for over five hours and at 185°F for more than four hours), destruction of Salmonellae was assured. This was shown by the calculation of lethal rates and by the failure to recover Salmonellae from the cooked turkey rolls, some of which contained Salmonellae prior to cooking. When internal temperatures of 65.6°C (150°F) and 71.1°C (160°F) were reached, over one million Salmonella senftenberg 775W cells were reduced to  $< 0.3$  organisms per cm<sup>2</sup> or per gram. However, even after 71.1°C (160°F) was attained, a positive isolation was obtained from one roll when the entire roll was swabbed. Since this work was done in the same room in which the rolls were inoculated, contamination could not be completely ruled out, although aseptic technique was used. The results of this thermal processing phase of the investigation confirm those of Wilkinson et al. (1965). They cooked rolls in ovens and failed to detect Salmonellae after internal temperatures of 71.1°C (160°F) were reached.

The adequacy of the cooking procedures could be nullified by recontamination. Cooling waters containing Salmonellae could contaminate the product by being sucked into the rolls along the clamp folds and at breaks in the casing during cooling. During many of the cooking operations observed in the plants, "leakers" were noted. The stresses of handling, cooking, or transferring the rolls to cooling tanks caused a few casings to break, and fluids leaked from the rolls during cooking. In cooling these rolls, contaminating bacteria could easily enter the product. Care should be taken in cleaning chill tanks, in repackaging of the leakers, and in draining excessive moisture to prevent contamination. Thus, recontamination appears to be the greatest public health hazard associated with turkey rolls processed by the procedures encountered in this study.

## CONCLUSIONS

1. Feed and trough water, as well as fecal-contaminated soil, are sources of Salmonellae on farms.
2. Turkeys are frequently infected with Salmonellae on the farm, and the infected birds carry these organisms to processing plants.
3. The predominant Salmonella serotypes recovered from turkey meat and the environment on any plant visit usually changed from visit to visit, from day to day, and among flocks processed on any one day; thus, it appears that turkeys coming into the processing plants are the major source of Salmonellae for turkey meat.
4. After individual serotypes reach the processing environment, they are readily disseminated to turkey products via processing equipment and workers' hands and gloves. Defeathering machines and equipment in the picking environment are important in the initial spread of Salmonellae to carcasses. Subsequent washing operations reduced Salmonellae from the surfaces of carcasses; however, washing failed to remove all the organisms from the turkey meat.
5. Finished turkey products are frequently contaminated by Salmonellae.
6. Over one million S. senftenberg 775W organisms are reduced to  $< 0.3$  cells per  $\text{cm}^2$  or per gram when internal temperatures of  $65.6^{\circ}\text{C}$  or  $71.1^{\circ}\text{C}$  are attained.



## SUMMARY

Tetrathionate selective enrichment was used for the isolation of Salmonellae. Lactose pre-enrichment was employed for hand rinse samples and for feed samples. Enrichment techniques were followed by brilliant green agar plating, triple sugar iron agar screening, and serological identification. Indicator bacteria were enumerated by conventional techniques. Internal temperatures of turkey rolls were recorded during cooking operations in processing plants and under controlled conditions in the laboratory.

Salmonellae were recovered on 37 of 48 visits (77%) to processing plants when these plants were engaged in "further processing" operations. More recoveries were made on days that freshly killed turkeys were processed (27 of 31 visits, 87%) as compared to days that thawed carcasses were processed (10 of 17 visits, 59%). As many as eight different serotypes were isolated during one visit, but usually one or two serotypes were found to predominate on the turkey meat as well as on the environmental contacts.

On the farms, Salmonellae were recovered from 9 of 97 feed samples and from 12 of 29 trough water samples. Salmonellae were recovered from fecal droppings obtained from 23 of 34 flocks at the farms supplying turkeys to Plant B and from 13 of 34 flocks arriving at this plant.

Twenty-nine of 46 samples (63%) of surfaces of carcasses were positive for Salmonellae after feather removal; whereas, these organisms were found on 18.2% of 33 carcasses after washing, on 10.6% of 50

carcasses before icing, and on 17.3% of 58 carcasses before packaging. Salmonellae were recovered from 14% of 150 samples of chilled, eviscerated turkeys. Defeathering equipment was frequently contaminated by Salmonellae (75 of 100 samples), and so was eviscerating equipment (50 of 155 samples). Four Salmonellae were found in 25 samples of equipment in the whole carcass packaging area.

Over one-fourth (26.8%) of 336 samples of finished turkey products, before cooking, were found to be positive for Salmonellae, and similar percentages (23.9% of 624 samples) of contact equipment and (31.4% of 102 samples) of workers' hands and gloves were observed.

Turkeys coming into the plants were shown to be the major source of Salmonellae on the finished products. On several occasions the microorganisms were traced from the farm to the plant. The incoming serotypes were detected in the plant for only a few days, at most, and were then replaced by other serotypes from subsequent flocks.

Twenty-five Salmonella serotypes were isolated from turkey meat or from the environment of two processing plants. Five additional serotypes were recovered from feed, water, or turkey feces. S. san diego and S. anatum were the most frequently isolated serotypes, although S. cerro, S. typhimurium, S. saint paul, S. blockley, and S. chester were also commonly encountered.

Salmonellae were not recovered from commercially cooked turkey rolls, although they were isolated from these rolls prior to cooking. The thermal processing procedures employed by both plants were adequate for destroying Salmonellae. Loads of more than one million Salmonellae

per cm<sup>2</sup> were reduced to less than 0.3 cells per gram and per cm<sup>2</sup> when internal temperatures of 65.6°C (150°F) or 71.1°C (160°F) were reached, and when turkey rolls were cooked at temperatures of 63°C (145°F) or higher for 4 hours.

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## ACKNOWLEDGMENTS

I wish to express my gratitude to the following people for their assistance in this investigation:

Dr. John C. Ayres, Department of Food and Dairy Industry, for his counsel, review, and constructive criticism on this work.

Dr. Allen A. Kraft, Department of Food and Dairy Industry, for his counsel, review, and critique of this investigation.

Dr. Donald S. Martin, Mr. Richard F. Clapp, and the Career Development Committees of the Communicable Disease Center and the Public Health Service for providing this opportunity for study.

The management and workers of the processing plants, turkey growers, U.S.D.A. inspectors, and local veterinarians, whose cooperation made this study possible.

Mrs. Mildred F. Galton and her staff, Communicable Disease Center, Atlanta, Georgia, for serotyping the Salmonella cultures.

Mrs. Mary H. Allen for typing this manuscript.

My wife, Ruth, and children, Steven and Sharryl, whose love and sacrifices as well as technical assistance made this course of study and investigation possible.